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WATER RESOURCES STUDY, MILFORD RESERVOIR PROJECT, KANSAS RIVER BASIN, KANSAS. STUDY OF POTENTIAL NEEDS AND VALUE OF WATER STORAGE FOR MUNICIPAL, INDUSTRIAL AND QUALITY CONTROL PURPOSES

Public Health Service
Kansas City, Missouri

March 1964

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WATER RESOURCES STUDY
MILFORD RESERVOIR PROJECT
KANSAS RIVER BASIN
KANSAS

Study of Potential Needs and Value of Water Storage for Municipal, Industrial and Quality Control Purposes

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VI
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WATER RESOURCES STUDY
MILFORD RESERVOIR PROJECT
KANSAS RIVER BASIN
KANSAS

A Study of Potential Needs and Value of Water Storage for Municipal, Industrial, and Water Quality Control Purposes

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VI
Kansas City, Missouri

and

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

In cooperation with

DEPARTMENT OF THE ARMY
U. S. Army Engineer District, Kansas City, Missouri

March 1964

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I. INTRODUCTION

Authority

In a letter dated March 13, 1962, the District Engineer, U. S. Army Engineer District, Kansas City, Missouri, requested that the Public Health Service "make an investigation of the Milford Reservoir Project as related to the present and prospective needs for municipal and industrial water supply and for the regulation of streamflow for pollution abatement and water quality control of the Kansas River."

The need for and value of municipal and industrial water supply storage are considered by the Public Health Service in accordance with the Memorandum of Agreement, dated November 4, 1958, between the Department of the Army and the Department of Health, Education, and Welfare relative to Title III of the Water Supply Act of 1958 (Public Law 85-500, as amended by Public Law 87-88). The need for and value of storage for water quality control are determined in accordance with provisions of the Federal Water Pollution Control Act (Public Law 84-660, as amended by Public Law 87-88).

The Milford Project was originally authorized by Congress in the 1938 Flood Control Act but was replaced by Harlan County Reservoir in 1944. It was reauthorized in the Flood Control Act of 1954. The original plan provided for a single-purpose flood control reservoir having 700,000 acre-feet of storage. It was modified during advanced planning to include 300,000 acre-feet of storage for anticipated future municipal and industrial water supply use in the Kansas River Valley under provisions of the Water Supply Act of 1958 (Public Law 85-500, Title III) at the request of the Governor of Kansas, who acted on the recommendation of the Kansas Water Resources Board. Although no specific identifiable needs of any city or entity were described, the request stated that it was the judgment of the Governor and of the Board that the need for such water supply would develop within a reasonable period of time. The request also indicated that future quality conditions were of equal concern and that, with the depletion of flows as a result of irrigation development in the upper basin coupled with anticipated municipal and industrial growth in the Kansas River Valley, the need for streamflow regulation for quality control would be expected to increase. On the basis of assurances of State participation in water supply costs, plans for Milford Dam were modified to provide conservation storage of 300,000 acre-feet. Construction was begun in 1962.

Subsequent to the request by the Governor of Kansas, the Federal Water Pollution Control Act was amended (Public Law 87-88) to authorize "inclusion of storage for regulation of streamflow for the purposes of water quality control" in Federal multipurpose projects. It further provided that the cost of such storage could be nonreimbursable if the benefits were determined to be widespread.

Purpose and Scope

The purposes of this study are to determine the quantities of water that will be needed for municipal and industrial water supply and for water quality control, to set forth the locations at which flow regulation will be needed, to identify the beneficiaries, and to estimate the benefits attributable to inclusion of storage in Milford Reservoir to meet these needs.

The primary area of influence of Milford Dam is the main stem of the Kansas River, but water draining from the entire basin affects the quality of water in the Kansas River and consequent flow regulation needs. Water supply and quality control needs for the next 100 years have been estimated.

Acknowledgments

The conduct of a study of this type depends to a large extent upon the cooperation of other Federal, State, and local agencies. The cooperation and assistance provided by the following agencies are gratefully acknowledged:

U. S. Department of the Army, Corps of Engineers, Kansas City District, Kansas City, Missouri

U. S. Department of the Interior, Bureau of Reclamation, Kansas River Projects, McCook, Nebraska

Kansas Water Resources Board, Topeka, Kansas

Kansas State Department of Health, Water Pollution Control Section, Division of Sanitation, Topeka, Kansas

II. SUMMARY AND CONCLUSIONS

Summary

1. Milford Reservoir is being built on the lower Republican River in the State of Kansas for flood control and other purposes, that may include water supply, water quality control, recreation, fish and wildlife, and navigation.

2. The 1960 population of the Kansas River Basin was 1,300,000, of which 700,000 resided in Subarea 6, the area draining directly to the Kansas River subbasin.

3. Available flows in the Kansas River exceed present municipal and industrial water supply needs.

4. Excessive concentrations of chlorides and sulfates occur on occasion in the Kansas River. The major sources of these chemicals are salt springs and seeps, salt marshes, and leaching associated with irrigation. Oil field brine wastes are reported to be substantially controlled under existing State laws.

5. Organic wastes discharged to the Kansas River have caused excessive water quality degradation, especially near the mouth of the river, during periods of low flow. Coliform densities were above the maximum level recommended for water supply use even with complete water treatment.

Conclusions

1. Substantial industrial and population growth can be expected in the Kansas River subbasin. It is estimated that the population of the Kansas River subbasin will increase to approximately 2,700,000 by 2060, the end of the design period.

2. The anticipated municipal and industrial water supply needs of the Kansas River Valley will exceed dependable flows of the Kansas River beginning about 1990. An average need of 268 mgd and a summer need of 356 mgd is expected in the suburban Kansas City area by 2060. At the present time an estimated 100 mgd is available for water supply purposes in the Kansas River so that as much as 256 mgd will be required to meet summer needs. It is estimated that storage to provide a draft on storage of 210,000 acre-feet per year will be needed by 2060.

3. Based on water quality objectives of 250 mg/l each for chloride and sulfate, it is estimated that storage to provide a draft on storage of about 70,000 acre-feet will be needed upon completion of authorized irrigation projects on the Solomon, Saline, and Smoky Hill Rivers. Substantial regulation is needed at this time but the amount will increase rapidly as authorized irrigation projects are completed and placed in operation. It is estimated that a draft on storage of 190,000 acre-feet will be needed by 2060. Storage needs to maintain mineral quality are based on continuing control of oil field brines, provision of adequate treatment facilities for any industry producing large mineral waste loads, and reasonable care in minimizing leaching of saline soils in irrigation practice.

4. Based on a water quality objective of 5 mg/l for dissolved oxygen and adequate treatment and control of municipal and organic industrial wastes at their source, it is estimated that flow regulation will be needed beginning about 1990 and that storage to provide a draft on storage of 150,000 acre-feet per year will be needed by 2060.

5. Since adverse mineral and dissolved oxygen conditions would not always occur simultaneously, storage needs to satisfy both objectives are larger than for either and it is estimated that storage to provide a draft on storage of 200,000 acre-feet per year will be needed for quality control purposes by 2060.

6. The Kansas Water Resources Board and the Kansas State Department of Health are carrying on an active program of water resources development requiring treatment of municipal and industrial wastes. Assurances should be obtained from these agencies that adequate treatment of waste effluents will be required of municipalities and industries discharging wastes to the Kansas River.

7. Allocation of conservation storage in Milford Reservoir to municipal and industrial water supply purposes will have a value estimated at $285,000 per year in terms of the cost of a single-purpose alternative project. Project costs have been discounted from 1990, the time of first need, to 1960.

8. Flow regulation will maintain acceptable mineral water quality for municipal and industrial use over the entire length of the Kansas River and maintain dissolved oxygen levels for public health, recreational and aesthetic purposes below Junction City, Topeka, Lawrence, and Kansas City. Allocation of conservation storage in Milford Reservoir to water quality purposes will provide a part of the regulation needed and will result in widespread benefits having a value estimated at $620,000 per year in terms of the cost of a single-purpose alternative project. Allocation of conservation storage in Milford Reservoir to both water supply and quality control purposes would result in benefits having a value between the values specified for either purpose, depending on the proportion allocated to each.

9. Water quality control releases should be based on frequent observation of quantity and quality of flow in the Kansas River at critical points of use throughout the period when such releases are needed.

10. The figures developed in this report can serve as a guide to the need for storage in other projects in the Kansas River Basin to meet water supply and quality control needs in the main stem of the Kansas River. However, the quality of water that will be stored in each reservoir determines its effectiveness in regulating water quality and its location determines the stream reaches in which it can control water quality. A detailed study should be made at each reservoir location to determine whether water supply or quality control storage should be provided.

11. A review and evaluation of the entire water resources program of the Kansas River Basin is needed so that the best use of all possible water resources projects can be considered for the greatest economic benefit to the entire basin. As water resources development progresses the entire program should be reviewed periodically so that additional development will be based on the best available information.

III. PROJECT DESCRIPTION

Milford Dam and Reservoir are located on the Republican River in Geary and Clay Counties in northeastern Kansas about 120 miles west of Kansas City, 60 miles west of Topeka, and 4 miles northwest of Junction City. The project site is about 8.3 river miles above the mouth of the Republican River, as shown in Figure 1. (Figure 1 is located at the back of the report.) Project purposes are flood control and perhaps water supply, water quality control, recreation, and navigation.

The Milford Dam will be a compacted earth structure 143 feet high with an uncontrolled chute spillway. Storage allocations, water surface elevations, and surface areas are indicated below:[18]

	Elevation feet	Surface Area acres	Storage Capacity acre-ft
Top of Dam	1,213	-	-
Flood Control	1,176.2*	32,300	700,000
Conservation**	1,144.4	15,600	300,000
Sedimentation***	-	-	160,000
Existing Channel	1,070	-	-
Total capacity below spillway crest			1,160,000

The discharge from the reservoir will be through a conduit with its invert at the elevation of the bottom of the reservoir. The discharge will be controlled by two 10.5-foot by 21-foot gate valves. Minimum flow releases will be controlled by two 2-foot square gate valves located at elevation 1087.

---

*Spillway sill.

**Conservation storage as referred to in this report is storage for water supply, water quality control, or irrigation purposes.

***Sedimentation storage is divided equally between the conservation and flood control pools.

IV. DESCRIPTION OF STUDY AREA

The study area considered in this report is the Kansas River Basin. Primary emphasis has been placed in the Kansas River Valley (Subbasin 6) as defined later in this section.

Description

The Kansas River Basin is described in previous reports of the Public Health Service,[1,5] Corps of Engineers,[24,38] and Kansas Water Resources Board.[8,16,25,39,41,50] These reports are the sources of the basic data in this section.

The Kansas River Basin is relatively long and narrow, extending almost 550 miles from eastern Colorado across southern Nebraska and northern Kansas to the Missouri River at Kansas City, Kansas, and Kansas City, Missouri. It has an area of approximately 60,000 square miles of which 56 percent is in Kansas.

The Kansas River, or the Kaw as it is often called locally, is formed by the confluence of the Republican and Smoky Hill Rivers near Junction City. It flows 170 river miles in an easterly direction to its confluence with the Missouri. The principal tributaries of the Kansas River are the Republican, Smoky Hill, Big Blue, and Delaware Rivers. The Solomon and Saline Rivers are major tributaries of the Smoky Hill River.

The Kansas River Basin climate is classified as subhumid. Rainfall increases from west to east and averages approximately 26 inches per year. Seventy-five percent of the annual precipitation occurs in the crop-growing season from April to September.

Water Resource Development

Milford Dam is one of 22 completed or authorized projects in the Kansas River Basin, as shown in Figure 1 and listed in Appendix A. Project purposes being considered are flood control, irrigation, water supply, water quality control, recreation, and navigation.[24] Modifications of storage allocations made since the Review Report on the Kansas River was issued have been in-

corporated in Appendix A. These reservoirs include Perry Reservoir on the Delaware River, on which a recent Public Health Service report was made, and Tuttle Creek Reservoir on the Big Blue River. These two projects, together with Milford, will have a dominant effect on streamflow regulation in the Kansas River from Junction City to its mouth.

Description of Subareas

The Kansas River Basin has been divided into six subareas on the basis of their effect on water supply and water quality in Milford Reservoir and in the Kansas River. These subareas are described below:

Subarea 1, the Republican River drainage area between Harlan County Dam and Milford Dam, comprises the area having primary effect on the quality of water in Milford Reservoir. For practical purposes only runoff from the 3,796 square miles below Harlan County and Lovewell Dams and flow releases and irrigation return flows from these projects contribute flow or degrade quality in Milford Reservoir in low flow years.

Subarea 2, the Republican River drainage area above Harlan County Dam, affects flow and water quality in Milford Reservoir through flow releases and irrigation return flows derived from Harlan County Reservoir. Harlan County Reservoir provides 150,000 acre-feet of conservation storage. Harlan County Dam, together with Lovewell Dam on White Rock Creek, controls an area of 21,107 square miles. There is a total of 411,000 acre-feet of conservation storage in Subarea 2 above Milford Reservoir.

Subarea 3, the Smoky Hill, Saline, and Solomon River drainage areas between Kanopolis, Wilson, and Glen Elder Dams and the junction of the Smoky Hill and the Republican Rivers, comprises the area having primary effect on the quality of water in the Smoky Hill River as it reaches the Kansas River near Junction City. Natural drainage from this area plus releases and irrigation return flows from Kanopolis, Wilson, and Glen Elder Dams on the Smoky Hill, Saline, and Solomon Rivers, respectively, will constitute the flow of the Smoky Hill River when Wilson and Glen Elder Dams are completed. Substantial quantities of sulfate and chloride are contributed to the Kansas River from this subarea.

Subarea 4, the Smoky Hill, Saline, and Solomon River drainage areas above Kanopolis, Wilson, and Glen Elder Dams, affects flow and water quality in the Kansas River through flow releases and irrigation return flows from the existing Kanopolis Dam and the Wilson and Glen Elder Dams, now under construction. These three reservoirs will have 440,000 acre-feet of conservation storage with an additional 62,500 acre-feet to be transferred from flood control to conservation (irrigation) when needed. With this addition, there is a total of 911,500 acre-feet of conservation storage in Subarea 4 in existing and authorized projects.

Subarea 5, the Big Blue River drainage area above Tuttle Creek Dam, comprises an area contributing a substantial flow of good quality water to the Kansas River. The existing Tuttle Creek Dam controls an area of 9,556 square miles. At the present time conservation storage in Tuttle Creek Reservoir has not been evaluated but constitutes a potential source for water supply and quality control purposes. A tentative allocation of 185,000 acre-feet to conservation storage has been made, as shown in Appendix A. In the absence of a definite assignment of storage, flow from Subarea 5 has been considered unregulated and the natural drainage from the basin has been included in the streamflow in the Kansas River.

Subarea 6, the drainage area below Subareas 1, 3, and 5, contributes a substantial flow to the Kansas River. The Kansas River Valley from Junction City to Kansas City, Kansas, is in this subarea. It is the area in which the Milford Project can be used for water supply and quality control purposes and in which major water supply and quality control problems are expected to develop.

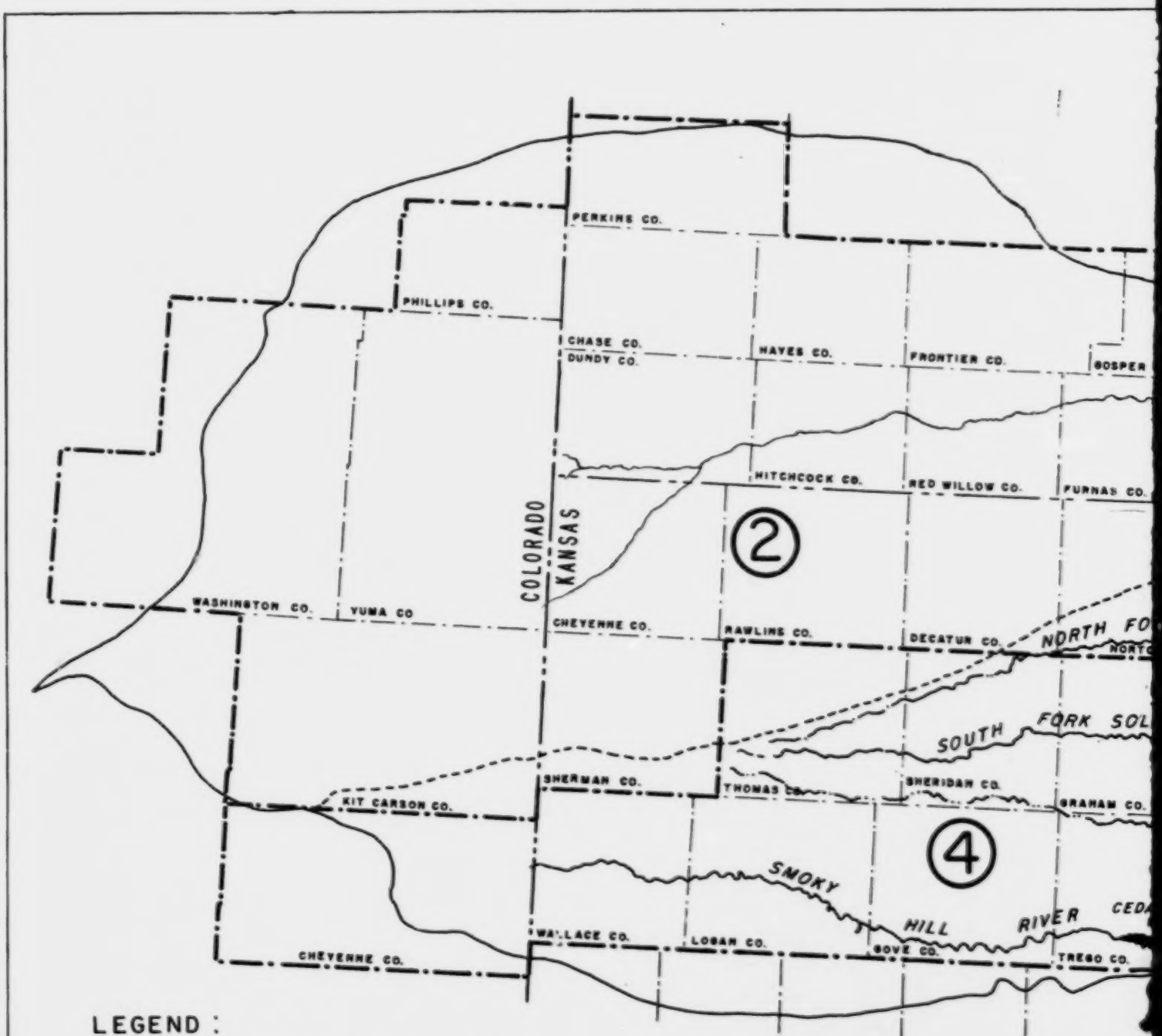
These subareas and the counties in each are shown in Figure 2.

Hydrology

Surface Water

The construction of major regulating structures in the Kansas River Basin has modified streamflow characteristics and long-term records of flow do not directly portray present and anticipated hydrologic conditions in the basin. The Kansas Water Resources Board, in cooperation with the U. S. Geological Survey, has prepared a series of technical reports that present in detail the present and prospective flow conditions in the Kansas River Basin.[16,17,23,49] The evaluation of flow regulation needs presented in this report is derived from the reports of the Kansas Water Resources Board, the Kansas State Department of Health, the Bureau of Reclamation, the Corps of Engineers, and the U. S. Geological Survey.

As a base for determining future water storage requirements, the quantity and quality of available waters are adjusted to conditions of water resource development expected in the near future. The adjustment includes the combined effects on water quantity and quality imposed by existing reservoirs or those under construction or authorized, existing irrigation or that under development, and existing municipal and industrial withdrawals and returns.



LEGEND :

① LOWER REPUBLICAN RIVER BASIN

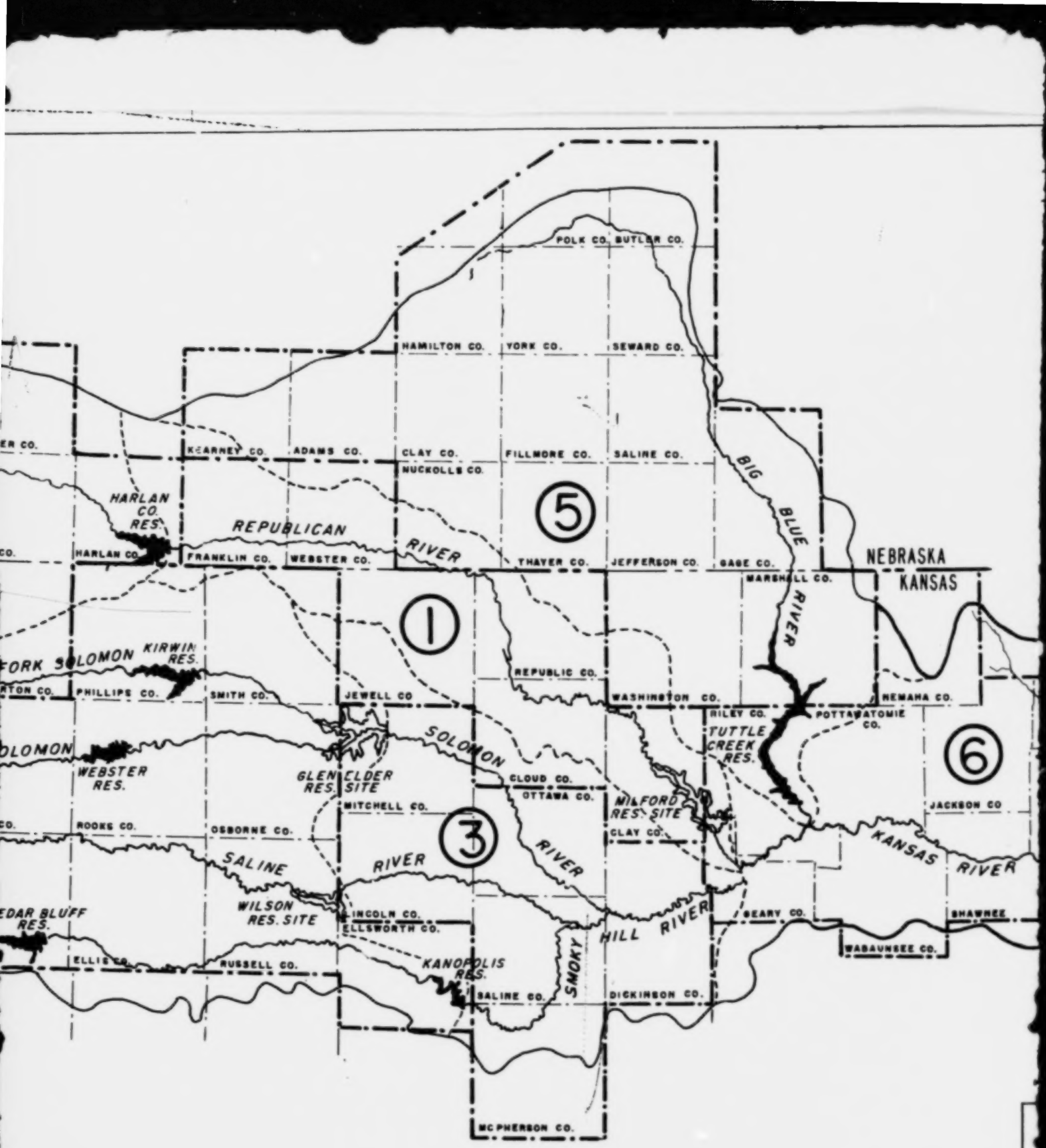
② UPPER REPUBLICAN RIVER BASIN

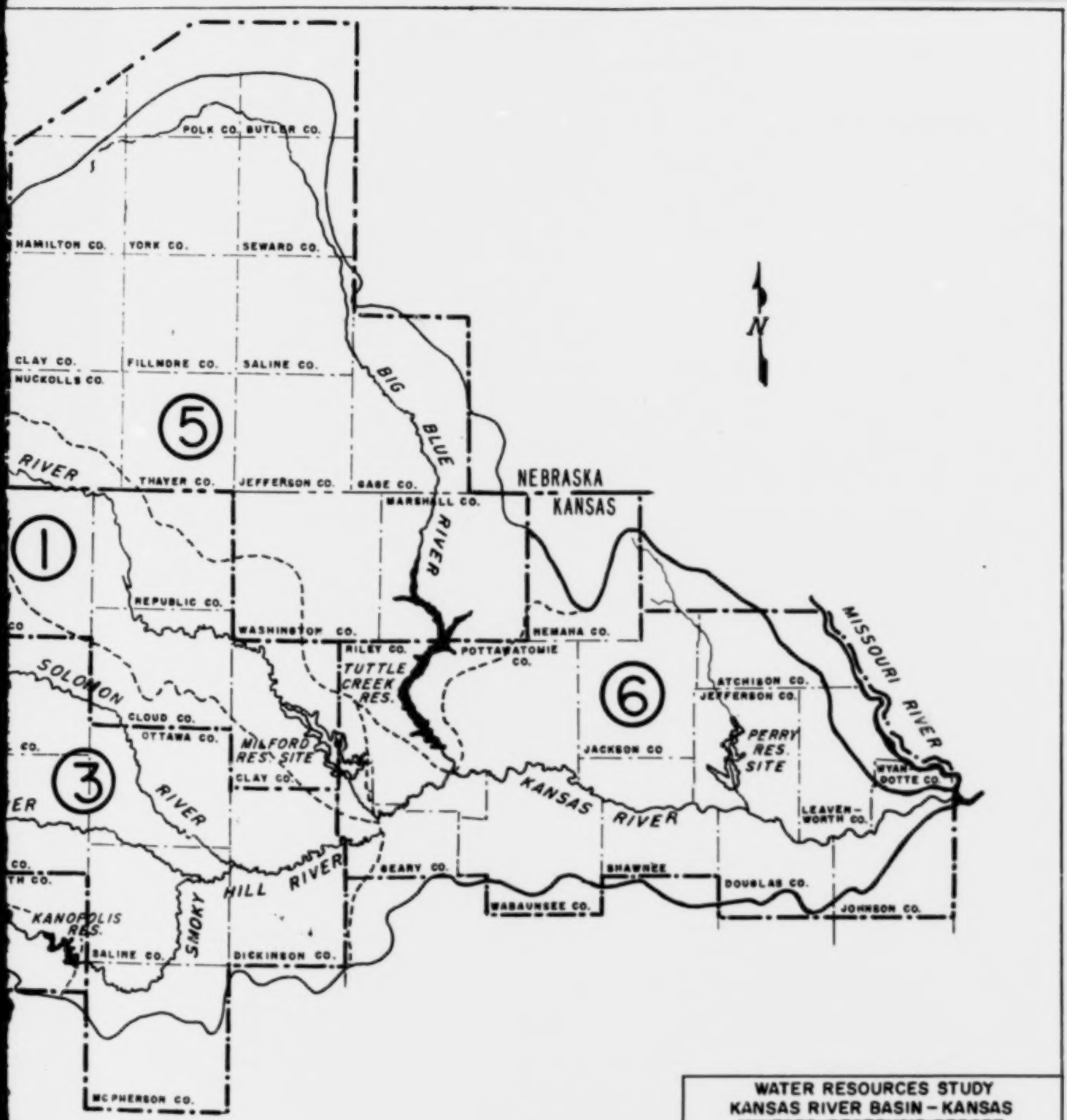
③ LOWER SMOKY HILL RIVER BASIN

④ UPPER SMOKY HILL RIVER BASIN

⑤ BIG BLUE RIVER BASIN

⑥ KANSAS RIVER BASIN


POLK CO.
BUTLER CO.
HAMILTON CO.
YORK CO.
SEWARD CO.
KEARNEY CO.
ADAMS CO.
CLAY CO.
FILLMORE CO.
SALINE CO.
NUCKOLLS CO.
HARLAN CO. RES.
REPUBLICAN
RIVER
HARLAN CO.
FRANKLIN CO.
WEBSTER CO.
THAYER CO.
JEFFERSON CO.
GAGE CO.
BIG BLUE RIVER
NEBRASKA
KANSAS
MARSHALL CO.
5
1
3
6
FORK SOLOMON
KIRWIN RES.
PHILLIPS CO.
SMITH CO.
JEWELL CO
REPUBLIC CO.
WASHINGTON CO.
NEMAHA CO.
RILEY CO.
POTTAWATOMIE CO.
TUTTLE CREEK RES.
SOLOMON
WEBSTER RES.
GLEN ELDER SITE
CLOUD CO.
OTTAWA CO.
MILFORD RES. SITE
JACKSON CO
MITCHELL CO.
ROOKS CO.
OSBORNE CO.
CLAY CO.
KANSAS RIVER
SALINE
RIVER
WILSON RES. SITE
LINCOLN CO.
ELLSWORTH CO.
CEDAR BLUFF RES.
ELLIS CO.
RUSSELL CO.
KANOPOLIS RES.
SALINE CO.
SMOKY HILL RIVER
DICKINSON CO.
GEARY CO.
SHAWNEE
WABAUNSEE CO.
MC PHERSON CO.



WATER RESOURCES STUDY
KANSAS RIVER BASIN – KANSAS
MILFORD RESERVOIR REPORT

LOCATION OF SUBAREAS

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PUBLIC HEALTH SERVICE
REGION VI KANSAS CITY, MO.

10-a

FIGURE 2

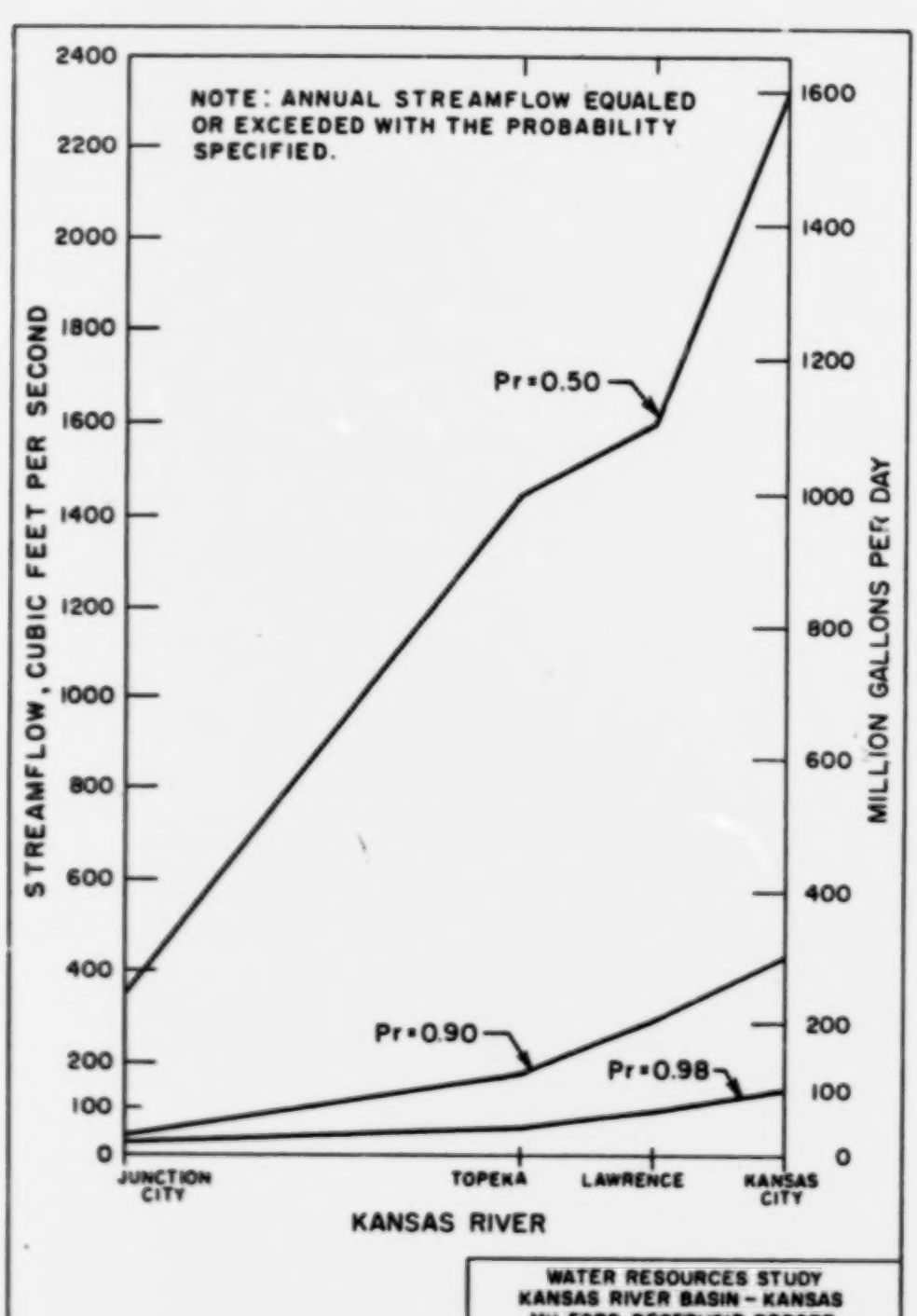
A high degree of streamflow regulation will be accomplished by the reservoirs in the basin. Consequently, the surface water supply of the study area is logically separated into three parts, two of which are of major importance in this study.

The first part, called the "dependable uncontrolled flow," is the runoff from drainage areas downstream from significant flow regulating structures. Its occurence is governed by natural phenomena and, hence, it is amenable to statistically description. The second part, called "dependable controlled flow," is the dependable contribution of reservoir storage allocated to conservation use. The release of dependable controlled flow, up to the dependable capacity of the storage facilities, is governed by the decisions of man; hence, the flow available at a given point or time depends on the purpose for which the water is allocated. The capacity of the storage facilities under a specified pattern of use can be described statistically in terms of recurrence probability. The third increment of streamflow is incidental or unpredictable reservoir releases, such as from flood storage, that can not be considered as part of the dependable supply.

Quantity of Dependable Uncontrolled Flow. The dependable uncontrolled annual mean streamflows at major water-use locations along the Kansas River are shown in Figure 3. The figure indicates, for example, that the probability is 0.9 that the mean annual flow from uncontrolled areas above Topeka for any one year will be equal to or greater than 200 cfs. Natural flows from controlled areas, as derived from the Kansas Water Resources Board report on low flow frequency,[23] were subtracted from natural flow at or near water-use areas to obtain the dependable uncontrolled flow. These data treatment involves the assumption that flows at different stations having the same probability of occurence are additive.

The differences in flow from month to month are more significant for water supply and quality control purposes than differences from year to year. A typical distribution of monthly flows has been estimated from a sample of records for the Kansas River at Topeka for years wherein the annual mean flow was near the long-term median annual flow. The following tabulation is considered representative of streams in the study area:

Month	Part of Annual Flow, percent
April	6
May	15
June	30
July	12
August	9
September	8
October	3
November	3
December	3
January	2
February	5
March	4


NOTE: ANNUAL STREAMFLOW EQUALED OR EXCEEDED WITH THE PROBABILITY SPECIFIED.
STREAMFLOW, CUBIC FEET PER SECOND
MILLION GALLONS PER DAY
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
100
0
1600
1400
1200
1000
800
600
400
200
100
0
Pr=0.50
Pr=0.90
Pr=0.98
JUNCTION CITY
TOPEKA
LAWRENCE
KANSAS CITY
KANSAS RIVER
WATER RESOURCES STUDY
KANSAS RIVER BASIN - KANSAS
MILFORD RESERVOIR REPORT
DEPENDABLE UNCONTROLLED ANNUAL MEAN STREAMFLOW KANSAS RIVER
DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VI
KANSAS CITY, MO.

11a

FIGURE 3

While the distribution is far from uniform, it is of interest to note that greater than average flows can be expected during the May-September period when water requirements are greatest.

Quantity of Dependable Controlled Flow. Relevant data furnished by the Corps of Engineers and Bureau of Reclamation on major reservoirs--existing, under construction, or authorized--that affect streamflow in the Kansas River are presented in Appendix B. The conservation yields shown in Appendix B are based on the flows that can be maintained in a 2 percent chance drought. The Corps of Engineers has indicated that, for planning purposes, these volumes of water can be considered available for withdrawal from storage whenever needed during the year.

Storage in Kanopolis, Wilson, and Glen Elder Reservoirs is allocated primarily to irrigation along the stream valleys below the respective reservoirs.[26,42] Consideration of municipal water supply and quality control need was made in Bureau of Reclamation reports based on conditions at one time of the 1949 Public Health Service report on the Kansas River Basin.[1,10] Irrigation return flows exceeded the flows needed for assimilation of municipal wastes in most cases and direct releases were seldom necessary. Consequently, irrigation return flows are assumed to be the only dependable and predictable contribution to streamflow in the Kansas River from these reservoirs.

Anticipated irrigation return flows below Kanopolis, Wilson, and Glen Elder Units which will contribute to flow in the Smoky Hill River are presented in Table 1.[26,42] The annual returns were distributed by months in accordance with the observed distribution in the Platte River Basin, which the Bureau of Reclamation has indicated it is using in projecting returns in the Kansas River Basin.

Since conservation storage in Tuttle Creek Reservoir has not been allocated to a specific use (January 1, 1963), flow from the Big Blue River drainage area is considered to be unregulated by the Tuttle Creek Dam in the evaluation of flow and hydrochemical conditions in the Kansas River. The unregulated annual mean flows in the Big Blue below Tuttle Creek Reservoir are:

Probability of Exceeding Indicated Flow	Annual Mean Flow		
	mgd	cfs	acre-ft/year
0.98	185	285	207,000
0.90	310	480	347,000
0.50	870	1,340	974,000

Because the flow of the Big Blue River is of good quality and substantial in quantity, allocation of this storage will have direct bearing on the needs for water from other reservoirs in the Kansas River Basin.

Table 1

Typical Irrigation Return Flows Anticipated
Below Glen Elder, Wilson, and
Kanopolis Reservoirs[a] - acre-feet

Period	Kanopolis	Wilson	Glen Elder	Total
April	800	700	1,200	2,700
May	900	800	1,500	3,200
June	1,000	900	1,700	3,600
July	1,100	1,100	1,900	4,100
August	1,400	1,300	2,300	5,000
September	1,500	1,400	2,500	5,400
October	1,400	1,300	2,300	5,000
November	1,100	1,100	1,900	4,100
December	1,000	900	1,700	3,600
January	900	800	1,500	3,200
February	800	700	1,300	2,800
March	800	700	1,200	2,700
Year	12,700	11,700	21,000	45,400

[a] Return flows listed are based on mean annual water use of 31,000 acre-feet, 28,600 A.F., and 50,400 A.F. at Kanopolis, Wilson, and Glen Elder, respectively, and constitute 41 percent of the water applied. In dry years water applied would be higher and return flows greater although the percent of return flow would be expected to be lower and the consumptive losses higher.

Dependable Uncontrolled Flow of Republican River at Milford Dam Site. Based on data for the years 1936-1957 unregulated annual flows into Milford Reservoir are estimated as:

Probability of Exceeding Indicated Flow	Annual Mean Flow		
	mgd	cfs	acre-ft/year
0.98	16.1	24.8	18,000
0.90	62.5	96.6	70,000
0.70	179.	276.	200,000
0.50	312.	483.	350,000

Ground Water

The alluvium of the Kansas River Valley is a very important part of the hydrologic system of the study area. The ground water and stream systems are interdependent. During periods of low streamflow, ground water discharges to the stream. When the stream level is above the ground water table, the river recharges the adjacent alluvium. Many wells in the valley actually draw part of their yield from the river.

Quantitative data are not available as to the actual amount of storage in the Kansas River Valley alluvium, the quantities withdrawn each year, the amount of annual recharge, or the development potential. However, it has been estimated on the basis of available information that the alluvium may hold from 1,000,000 to 2,000,000 acre-feet of water in storage. The average recharge has been estimated to be about 10 percent of the precipitation, or about 50,000 acre-feet per year for the entire valley.[16]

The average recharge rate of 50,000 acre-feet per year constitutes the upper limit of the safe average annual withdrawal throughout the valley that can be considered supplemental to the dependable uncontrolled streamflow. The volume of ground water recovered by wells each year is considerably less than 50,000 acre-feet. The ground water system, i.e., recharge rate, economical well spacing, permeability of the aquifer, etc., not the volume of water in storage, control the quantity that can be practically developed on a sustained basis. There is need for more information regarding the rate of recharge from precipitation and the interrelationship between ground water in the alluvium and the surface water in the river. The Kansas Water Resources Board has called attention to this need in its report on the Kansas Unit.[16]

V. ECONOMICS

An assessment of the water resource development needs of the Milford Reservoir study area necessarily involves an appraisal of its industrial and population growth potential as a basis for estimating future industrial and municipal water use.

Economic Growth

An estimate of prospective economic expansion in the Milford Reservoir study area can be derived from an examination of past industrial growth rates as compared with other areas in the United States as well as with the nation as a whole.* The differences in growth rates reflect the basin's relative competitive position in supplying goods and services for the local as well as for the national and world markets.

Many factors affect the comparative economic advantage of a particular region.** An appraisal of each factor is not warranted for the present study. Instead, the relative competitive advantage or "pulling power" of the study area was estimated from gross measures of relative employment change in various industries between the study area and the nation. These trends in themselves are a reflection of the composite effect of all factors affecting the location of the specific industries. The estimates were modified as

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*Data in this section were largely obtained from the following publications of the Bureau of Census and the Bureau of Mines: Census of Population, Census of Manufactures, Agricultural Census and Minerals Yearbook. Valuable additional information was obtained from representatives of the State Government and universities. Separate publications are indicated in the Bibliography.

**Among them are relative costs of production and distribution and social amenities, which in turn, depend upon the availability and quality of natural resources; cost of water, fuel, and other utilities; size of the market; economies of scale; availability and cost of requisite labor skills; price of buildings and building sites; transportation costs; tax structure; presence of complementary and supplementary industries; and social amenities such as recreational facilities.

appeared warranted by the quantity and quality of natural resources of the area, by the trends in employment ratios, and by the consistency of the estimates with conventional gross population projections. In addition, comparisons were made with the projections of others.[22,29]

Industrial Employment Trends[45,46,47,48]

A preliminary review of industrial employment in Subareas 1 through 5 indicates that in 1960 these areas comprising 85 percent of the basin's area had only 45 percent of the population and 25 percent of the manufacturing employment. The areas are primarily agricultural and have relatively little industry. On the other hand, Subarea 6, the Kansas City-Lawrence-Topeka area, is relatively densely populated and has a higher proportion of manufacturing and service industries.

In the western section of the basin agriculture remains the dominant base of the economy even though it has undergone a significant decline, especially since 1950. The number of farm workers decreased from 103,000 in 1940 to 66,000 in 1960--a rate of decrease that coincided with that of the nation as a whole. This decrease was offset by a 60 percent increase in both manufacturing and service employment that absorbed most of the unemployed workers leaving little change in total employment during the 1940-1960 period. The number engaged in manufacturing increased from 8,000 to 13,100 and the number engaged in service-type industries increased from 97,300 to 141,000.

Employment in the Kansas City-Topeka area (Subarea 6) increased at a more rapid rate than that of the nation between 1940 and 1960. The number of workers in both manufacturing and service industries doubled from approximately 23,000 to 45,000* and from 101,000 to 209,000, respectively, during the 20-year period. The general trend in these industries was similar for all three major cities--Kansas City, Kansas, Lawrence, and Topeka--as well as for the other counties in Subarea 6. However, their relative significance in each of these cities varies. Manufacturing employs one-fourth of the labor force in Kansas City but only 12 percent in Lawrence and Topeka. Conversely, employment in the service-type industries is relatively greater in Lawrence and Topeka, largely because of the number employed by the University of Kansas, the Kansas State Government, and the United States Armed Forces.

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*Increased diversification has accompanied the rapid rise in manufacturing employment. In the whole of subarea, there was an increase in the number of workers between 1940 and 1960 in all categories, except (1) furniture, lumber, and wood products and (2) food and kindred products.

The extractive industries are of less importance in Subarea 6 than manufacturing and service industries so far as employment is concerned. Agricultural employment decreased almost 50 percent from 28,500 in 1960 to 15,100 in 1960, dropping from 16 percent to 5 percent of the labor force.

Industrial employment in each of the Kansas River Basin subareas and in the major metropolitan areas is shown in Appendices C and D.

Economic Outlook[6,16,22,29,30,39,41,50,51,53]

Growth prospects in Subareas 1 through 5 are not very promising. Agricultural production will continue to increase, because of an expansion of irrigation. However, farm employment will probably decrease further in response to improvements in agricultural science and technology. The extraction of mineral resources, particularly petroleum and gas, will probably increase, but will not affect employment measurably. Manufacturing based on these resources is likely to gravitate to larger markets in or adjacent to metropolitan areas outside Subareas 1 through 5.* Thus, manufacturing is not expected to rise significantly.

A continuation of industrial expansion in Subarea 6 is indicated by the comparative analysis of past growth trends between the basin and the nation. The employment increase in the eastern part of the Kansas River Basin has exceeded the national average. The relative increase as well as the absolute growth of manufacturing employment attest to the economic advantages of the Kansas River Valley for basic industries, from which further induced employment will be derived. The proximity to regional and national markets, the availability of local resources, convenient transportation, and an established, diversified industrial base make a setting favorable to continued expansion in production and employment. Appendix E depicts the estimate of industrial employment in each of the five major cities in Subarea 6, the remainder of the subarea, and the subarea total.

Population Trends

In the western part of the basin the rural population** dropped from approximately 550,000 in 1910 to 250,000 in 1960. Total population in the

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*Of the 361 municipalities in Subareas 1 through 5, only 32 had a population in excess of 2,500 in 1960. Only Salina (43,202), Kansas, had a population over 25,000.

**Rural population is defined in this study as the population living outside of towns or cities regardless of their size.

329 communities with less than 2,500 residents in 1960 remained essentially unchanged during the last 40 years, fluctuating between 160,000 and 170,000. Only in the urban places (cities of 2,500 population and over) did population register a positive growth trend. The total population in these 32 urban places increased steadily from about 100,000 to 200,000 during the 1910-1960 period. Although the growth rate for the urban places was greater than the rate of population decline in the rural areas, the absolute decrease in the latter was greater than the gain in urban population. The net result was one of total population decline in each of the last three decades. The general pattern of decline in the rural population, of increase in urban population, and of no change in the other smaller municipalities held true in each of the subareas in the western part of the basin,* as is shown in Figure 4.

Rural population is expected to decrease still further to 140,000 by 2010 and then remain essentially constant to the end of the study period. Total population of cities below 2,500 is estimated to decrease from 170,000 in 1960 to 100,000 by 2060 in response to a decline in service-type employment stemming from a diminution in rural population. The increased ease of traveling and the greater range of commercial and business services available in the larger cities are also factors in the decline of the smaller communities.

The urban places in this area are exceptions to the trend of population loss. They have grown faster than the national average during the last 50-year period and are expected to continue to increase. The total population of urban places is forecast to reach 480,000 in 2060 from the present population of 200,000. Because of the depressing effect of the anticipated decline in the small cities and rural areas, the total population in Subarea 1 through 5 is estimated to experience only a modest increase from 600,000 in 1960 to 670,000 by 2060, as shown in Figure 5.

The population of the Kansas River Valley grew relatively slowly through the 30 years from 1910 to 1040 but has shown a rapid increase since 1940. Between 1940 and 1960 it grew 2.0 percent per year compared to the national average of 1.6 percent per year. Within the area, however, there was a wide range in population growth rates. The three larger cities--Kansas City, Topeka, and Lawrence--increased at a more rapid rate than the average city of their size group in the United States. In the remainder of Subarea 6 (the counties other than those wherein the above cities lie) the urban population registered a slow, steady rise for the last 40 years, while in the smaller communities (less than 2,500 population) the population has been essentially stable. The rural population decreased at a relatively steady rate during the last 50 years from approximately 105,000 to 85,000.

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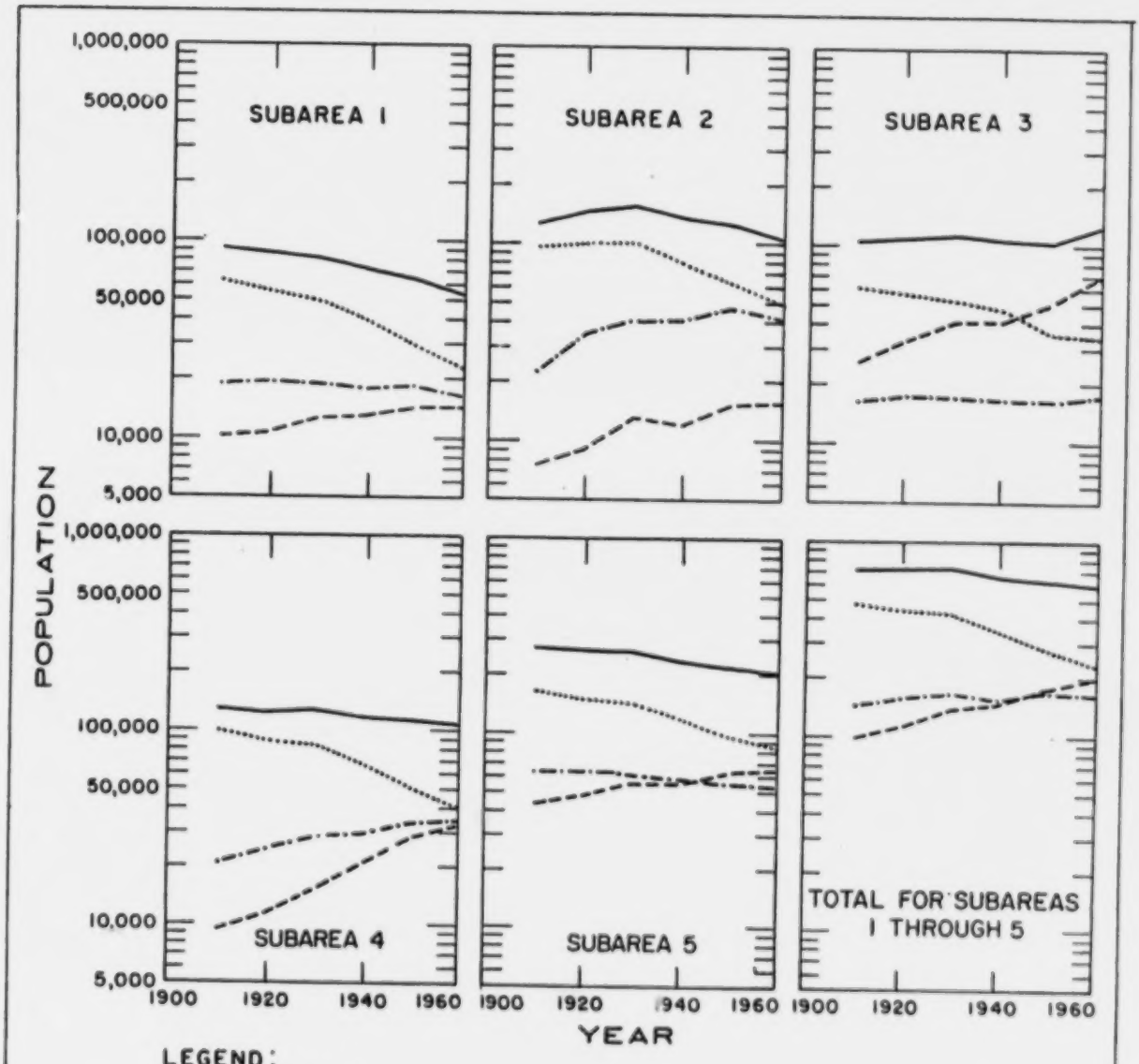
*The apparent exception is in Subarea 4 where the increase in the total population living in the smaller cities was primarily due to the establishment of more of these small communities during each of the decades rather than to the growth of existing ones.



LEGEND:

——— TOTAL

– – – – URBAN-POPULATION IN CITIES OF 2500 OR GREATER FOR ANY CENSUS YEARS.

·–·–·– OTHER URBAN-POPULATION IN CITIES OF LESS THAN 2500 FOR ALL CENSUS YEARS.

····· RURAL-POPULATION NOT RESIDING IN CITIES

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POPULATION TRENDS
SUBAREAS 1 THROUGH 5

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FIGURE 4

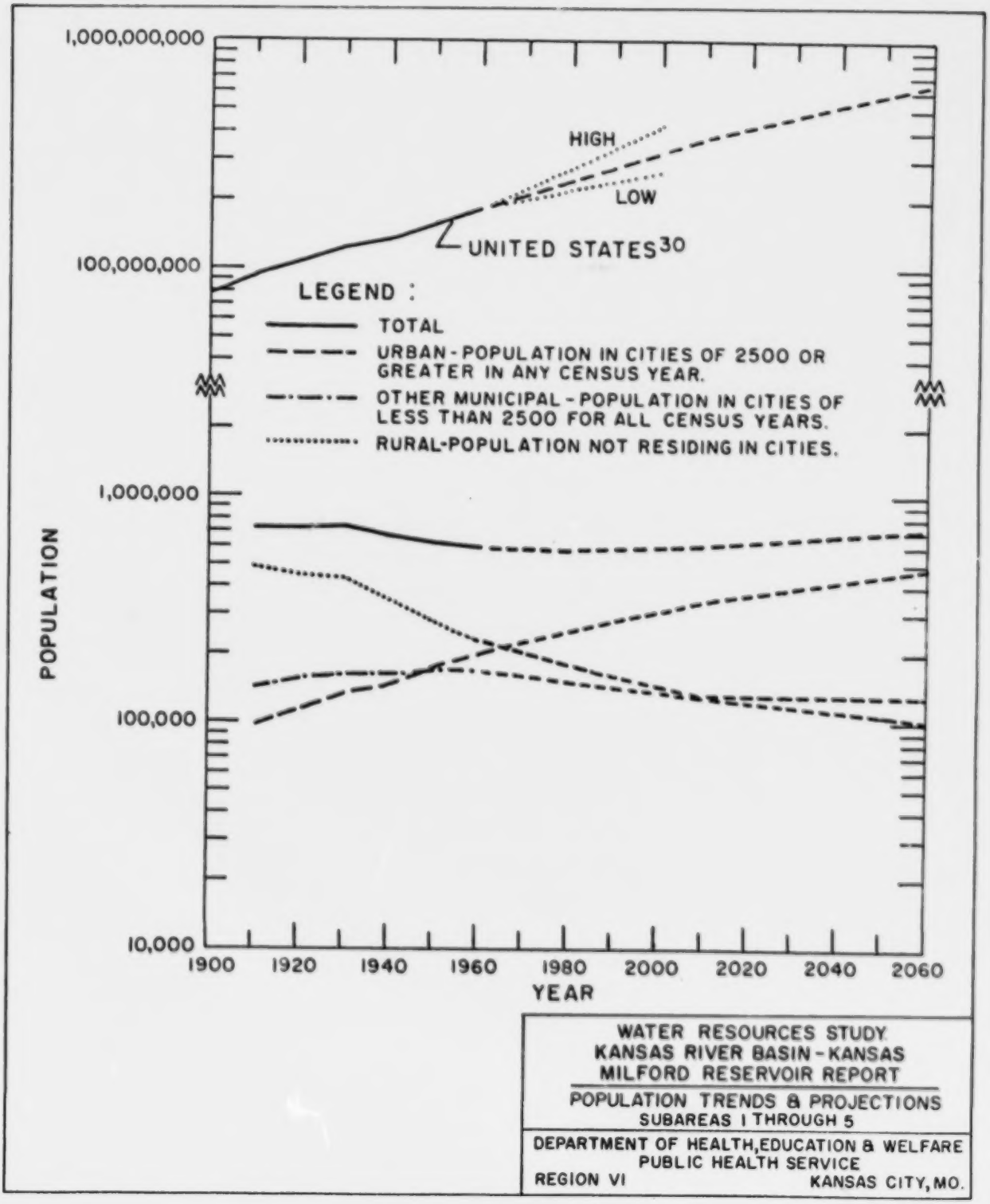
1,000,000,000
100,000,000
1,000,000
100,000
10,000
POPULATION
HIGH
LOW
UNITED STATES[30]
LEGEND :
TOTAL
URBAN - POPULATION IN CITIES OF 2500 OR GREATER IN ANY CENSUS YEAR.
OTHER MUNICIPAL - POPULATION IN CITIES OF LESS THAN 2500 FOR ALL CENSUS YEARS.
RURAL-POPULATION NOT RESIDING IN CITIES.
1900
1920
1940
1960
1980
2000
2020
2040
2060
YEAR
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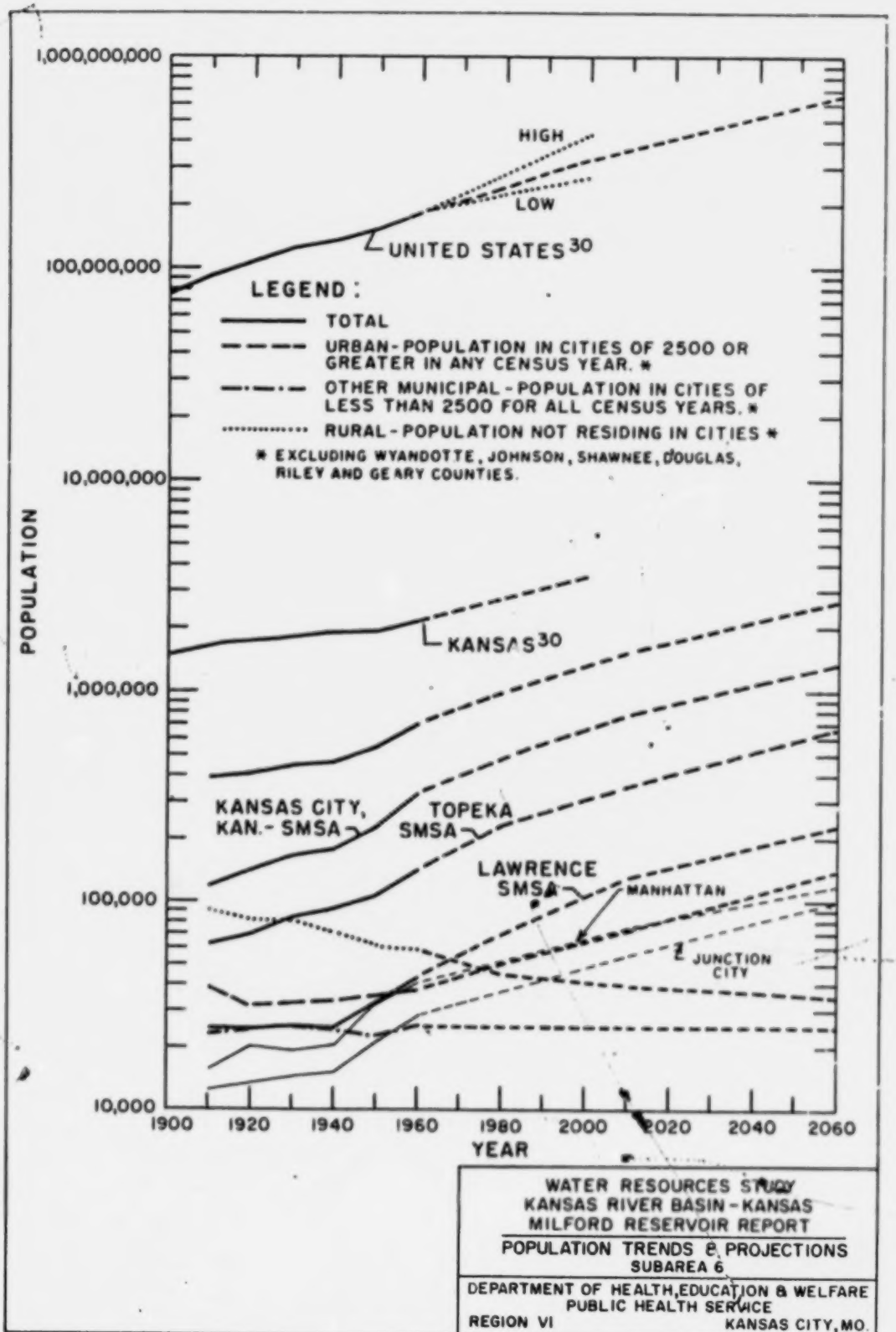
FIGURE 5

The growth in Subarea 6 is expected to coincide closely with the rate of increase for the United States, as shown in Figure 6. The population forecost indicates an increase from 710,000 in 1960 to 2,700,000 by 2060. The growth of major cities is also shown in the figure. Junction City with 18,700 and Manhattan with 23,000 in 1960 are estimated to reach 100,000 and 120,000, respectively, by 2060.



WATER RESOURCES STUDY
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POPULATION TRENDS & PROJECTIONS
SUBAREA 6

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FIGURE 6

VI. MUNICIPAL AND INDUSTRIAL WATER SUPPLY

Present

Existing ground and surface water supplies for the Kansas River Basin have been tabulated in the Kansas Water Resources Board reports[16,39,41,50] and in the municipal water facilities inventories[20,28] prepared by the Public Health Service on the basis of data supplied by the Kansas State Department of Health. Shallow wells, largely in the valley alluvium of the stream near which they are located, supplied a reported 176,654 people in Subarea 6 of the Kansas River Basin in 1963. An additional 2,555 persons were supplied by deep wells. These well systems supplied an average of 15.7 mgd. Impounded water supplies provided 2.2 mgd for 19,575 people in six cities in 1963.

By far, the largest water use was from surface sources. Surface sources in Subarea 6, primarily in the Kansas River Valley, served 172,630 people at Topeka, Lawrence, Onaga, and Valley Falls in 1963. Average withdrawals were 18.3 mgd. Approximately 160,000 persons used 5.6 mgd from rural supplies which came from wells, cisterns, and farm ponds. Municipal water use in the study area is tabulated in Appendix F.

Most of the industries located in the Kansas River Valley purchase water from municipal systems.[16] Only limited data are available on their needs. The 1962 Public Health Service Inventory of Municipal Water Facilities, currently in preparation, includes estimates of the industrial, or the combined industrial-commercial, use. Although the data are fragmentary and are not usable to project future industrial water supply needs of the basin, they indicate that municipal water use includes considerable quantities for industrial purposes.

The Kansas Water Resources Board[16] indicated the existence of 58 vested rights, appropriative rights, or pending appropriative rights to withdraw 232,500 acre-feet of water in Subarea 6 as of June 1957. Most of the rights were for ground water, although the largest volume was from surface sources. The largest volume covered by these rights, amounting to about 100,000 acre-feet per year, is for surface water for cooling at plants of the Kansas Power and Light Company at Lawrence and Tecumseh. The Sunflower Ordinance plant near DeSoto uses considerably less than its surface water right of 6,500 acre-feet per year at the present time. Ground water rights

in Subarea 6 totaled 88,000 acre-feet in 1957 but data on the actual amount withdrawn are not available. Extensive development of ground water in the alluvium adjacent to the Kansas River undoubtedly intercepts water that would otherwise sustain flow in the Kansas River or even induce infiltration from the river.[16]

Future

Estimates of future water supply needs are based on the growth of employment and population presented in the economics section of this report and on unit water use per person or employee set forth below.

Unit water use in the study area has been estimated from regional and national trends reported by the Senate Select Committee on National Water Resources[31] and by the U. S. Bureau of Census in its Census of Manufactures and from municipal water use reported for communities in the study area by the Kansas Water Resources Board.[16]

Municipal water use has been increasing in recent years.[11,31] Nationally the Senate Select Committee estimated that use would increase from 147 gallons per capita per day (gpcd) in 1954 to 152 gpcd in 2000, but indicated that the estimate was considered to be conservative. Requirements of as high as 225 gpcd by 2000 with a possible leveling off thereafter were discussed. Present water use in Kansas River Valley is below the national average. Substantial increase is expected with provision for more adequate supply, with the extension of water service to a greater proportion of the population and with increased use of water-using appliances.

Considering the long period over which the estimates apply, that more detailed studies are contemplated in the near future, and that revisions of the water resource development plan will be possible in the future, estimated per capita water use somewhat above the national average figures cited are considered reasonable and desirable to assure that the water needs of the area will be met.

In addition to domestic use, municipal use generally includes commercial, public and fire needs as well as the needs of many of the industries within the community. Provision must also be made for unavoidable losses during treatment and distribution of the water.

Present and projected per capita use (gpcd) on which municipal water needs for each of the major water service areas in the Kansas River Valley are based are listed below:

	1956 (est.)	1980	2010	2060
Junction City	143	150	160	175
Manhattan	140	150	160	175
Smaller Towns & Rural	140	150	160	175
Topeka	105	150	160	175
Lawrence	150	160	170	175
Kansas City, Suburban	120	135	150	160

It is understood that the Kansas Water Resources Board has estimated considerably higher per capita water use in its reports, and is now reviewing trends in water use to provide a better basis for estimating future water resource development needs.

Since the availability of water varies seasonally, water needs have been adjusted for seasonal variations. Summer (June, July, and August) and winter (December, January, and February) use have been estimated to be 120 and 90 percent of normal, respectively. While maximum summer use in drouth years has been observed to be substantially higher, consideration of carryover storage indicates that it is not necessary to increase requirements in drouth years for purposes of estimating water supply storage requirements since drafts on storage will extend over several years. Consumptive losses resulting from municipal and industrial use and from reservoir evaporation constitute a considerable water supply demand that must be considered in estimating storage requirements. For purposes of this report, consumptive losses in municipal use were estimated to be 20, 30, and 50 percent of normal water use during winter, spring and fall, and summer periods, respectively. It is assumed that evaporation losses will be considered in estimating yield capabilities of each reservoir.

The estimated municipal water use refers to domestic and industrial use for other than major water-using industries. Water supply needs of the major water-using industries of importance in the Kansas River Valley are considered separately. This method of analysis is not intended to imply which industries will obtain their water from municipal sources or which will be self-supplied, but rather is a method for making a long-range forecast of future needs.

Based on the economic analysis the chemical and food processing industries constitute the major water-using industries that are presently important and are expected to have substantial growth in the study area. Provision for ample water of suitable quality for industrial growth is one

of the reasons for conservation storage in Milford Reservoir. However, present water use by these industries is less than one-half of the national average per worker. Present national trends toward greater automation and increased productivity per worker will require greater quantities of water, but based on industrial water use in the Kansas River Basin in the past, it is expected that use per worker will continue to be at a lower rate than the national average.

Present and projected water use in gallons per worker per day on which the water supply needs by the principal water-using industries of importance in the Kansas River Valley are based are listed below:

	1958	1980	2010	2060
Food Processing	2,500	3,350	5,280	8,700
Chemical & Allied Products	8,000	10,800	16,800	28,000

The report of the Senate Select Committee on National Water Resources on water needs of the principal water-using industries[32] and the reports of the Bureau of Census were the primary references.

Winter, spring and fall, and summer use was estimated to be 90, 100, and 120 percent of the annual average value, respectively. Consumptive use was smaller than for municipal purposes, and was estimated to amount to 10, 20, and 30 percent of normal water use for the winter, spring and fall, and summer periods, respectively.

The estimated present and future municipal and industrial water needs for the use areas of the Kansas River Valley are shown in Appendix G. For purposes of this report population of the entire county in which each of the major communities are located has been the basis for analysis of water supply needs (except at Kansas City, Kansas). As urban areas expand with anticipated population growth the extension of municipal water service is considered essential to assure safe water in adequate quantity to all water users.

Consumptive losses from power generation were estimated on the basis that excess heat would be dissipated in the stream after once-through cooling and would result in evaporation of one percent of the water used. Future power production and water losses, estimated from the Senate Select Committee on National Water Resources report on electric power,[34] are:

	1958	1980	2010	2060
Power Production, kw-hr/capita/year	4,200	8,000	11,000	15,000
Cooling Water Use, gal/kw-hr	53	50	45	45
Evaporation, gpcd	6.1	11.0	13.6	18.5

Water use for irrigation was estimated from the Kansas Water Resources Board report on the Kansas Unit[16] and the Bureau of Reclamation review report on the Kansas River Basin.[10] While irrigation development in the Kansas River

Valley is small at the present, it is considered probable that irrigation use will continue to expand until it reaches a maximum level by about 2010. Present use is about 0.9 acre-feet per acre per year for land under cultivation and it is not expected to change significantly in the future. Consumptive use is estimated to amount to 60 percent of withdrawals over the irrigation season. Estimated irrigated acreage, total water use, and return flows are indicated below:

	1960	1980	2010	2060
Irrigated, Land, acres	25,000	80,000	103,000	103,000
Total Water Use, acre-ft	23,000	73,000	96,000	96,000
Return Flow, acre-ft	9,000	29,000	38,000	38,000

The monthly distribution of water use for irrigation and the time at which return flows would reach the Kansas River were estimated to determine the needs for water released from storage. Water use normally extended from May through September with the peak in July, while return flows were estimated to reach the Kansas River in the months of July through October with peak in September. The values used are listed below:

	May	June	July	Aug	Sept	Oct	Annual
Use, percent of annual use	9	17	42	18	14	0	100
Return, percent of annual use	0	0	4	12	16	8	40

Any reduction in irrigation usage would tend to increase the available supply, although not to the extent of the reduction in use since substantial withdrawals take place in the spring when excessive streamflow is normally available. A separate analysis of water requirements in the absence of normal irrigation use has not been made in connection with this report.

Streamflow Regulation Needs

The annual streamflow regulation to satisfy municipal and industrial water needs at each of the major use areas from Junction City to the mouth of the Kansas River has been assessed in terms of a 98 percent probability of meeting the requirement throughout the year. This is considered to be in accordance with good engineering practice for water supply development. The computations have been made on the premise that water of whatsoever quality received constitutes a supply if sufficient in quantity.

Annual streamflow regulation, or draft on storage, has been determined as the sum of the deficiencies of available flows to meet water supply needs on a month-by-month basis. Available flows at the various points of use have been estimated as the sum of the dependable uncontrolled flow below

all regulating structures, the dependable uncontrolled flow from the Big Blue drainage area, inflow to Milford Reservoir and irrigation return flows anticipated from Kanopolis, Wilson, and Glen Elder Units after full development, less anticipated consumptive losses upstream of the point of use. The calculated draft on storage volumes have been increased by 25 percent to cover such items as synchronization of reservoir releases with downstream needs, conveyance losses, atypical flow conditions and unforeseen requirements.

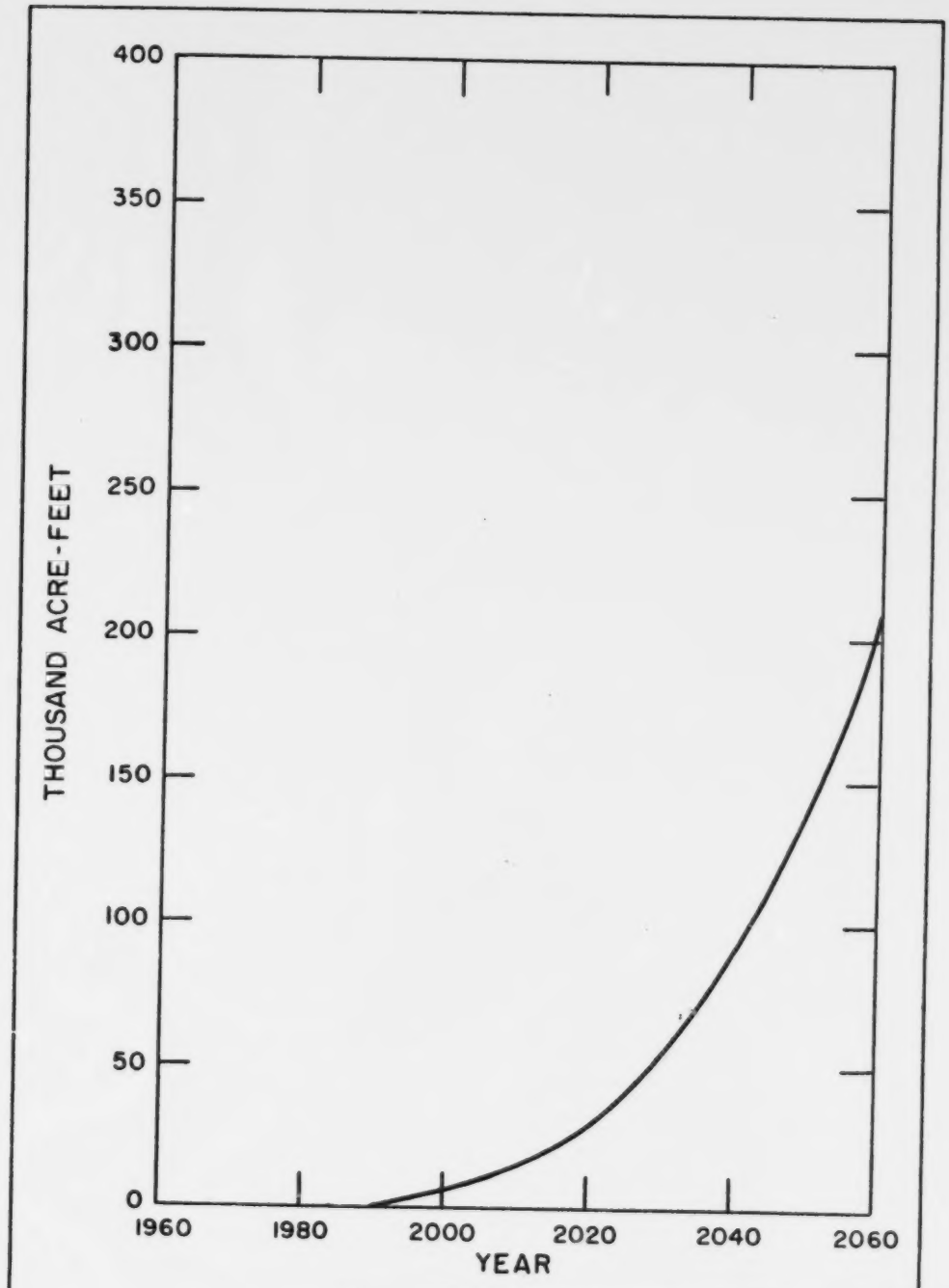
The foregoing analysis can be refined by more detailed scheduling of flow needs in terms of temperature, local rainfall, detailed information on seasonal industrial waste loads, daily flow records, etc. For purposes of long-range forecasts these estimates are adequate and show that considerable storage is needed for anticipated municipal and industrial water supply needs of the Kansas River Valley.

Figure 7 shows the draft on storage estimated for water supply needs that will develop by 2060 in Junction City, Topeka, Lawrence, and the suburban areas south and west of Kansas City. Provision of storage to assure a draft of 210,000 acre-feet of water will assure that estimated municipal and industrial water supply needs will be met at all of the water service areas along the Kansas River in a drouth year occurring on an average of once in 50 years. Considering the reuse of water possible if quality is maintained at a satisfactory level, storage needs at the communities along the river are not additive.

Municipal and industrial water supply storage needs in the major water service areas of the Kansas River Valley are:

Junction City. Present use is reported to be 2.5 mgd. The source is wells having a capacity of 6 mgd located along the banks of the Republican River. An emergency intake in the Republican River is available. While the Smoky Hill River would also be available, its poor quality at times of low flow would be expected to limit its use. Future municipal and industrial water supply would be expected to come from the Republican River either directly or through additional wells on the river banks and is expected to reach 24 mgd by 2060. A summer use of 33 mgd can be anticipated. Streamflow regulation will be needed beginning about 2000 and will require a draft on storage of the order of 20,000 acre-feet by 2060. This draft could be supplied by Milford Reservoir.

Manhattan. Present use is reported to be 3 mgd. The source is shallow wells having a capacity of 7.5 mgd located in the Kansas River Valley alluvium. Future water requirements for municipal and industrial purposes are estimated to reach almost 30 mgd by 2060. Summer use would reach 40 mgd by that date. The additional water that could be secured from



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KANSAS RIVER BASIN – KANSAS
MILFORD RESERVOIR REPORT

ESTIMATED ANNUAL DRAFT ON STORAGE FOR WATER SUPPLY USE

DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VI KANSAS CITY, MO.

25-a

FIGURE 7

ground water sources is not known but on the basis that Topeka and Lawrence turned to the Kansas River as their source of supply as their demands increased, it may be expected that Manhattan will do the same.

Available flows in the Big Blue and Kansas Rivers are sufficient to provide water supply needs through 2060. Accordingly, it is concluded that there is no need for water supply storage for Manhattan in the Milford Reservoir.

Small Communities and Rural Areas Above Topeka. Present municipal use in the smaller communities and domestic use in the rural areas between Manhattan and Topeka is less than 10 mgd at this time. Future use for municipal, industrial, and domestic purposes is estimated to reach 40 mgd in the area by 2060. Present use is largely from ground water sources. While the Kansas River Valley ground water supply is presently overscribed, many of these uses are small and widely dispersed and continued use of ground water is expected. For the small towns of the area much of the increase will necessarily come from surface sources or deplete the ground water source to such an extent that streamflows will be affected.

Much of the use would be from local streams or perhaps local impoundments rather than the Kansas River. Available flows in the Kansas River would be in excess of all needs of the area. It is concluded, therefore, that no provision for these needs is necessary, except insofar as consumptive use affects downstream needs.

Topeka. Present use is reported to be 13.4 mgd. The primary source is the Kansas River (intake capacity, 38 mgd). Wells in the river alluvium provide an estimated 2 mgd. If all of Shawnee County were served by a central water system, use would be expected to be about 22 mgd. Future water needs for municipal and industrial purposes are estimated to reach 180 mgd by 2060. Summer use would be expected to reach 238 mgd by the end of the design period.

The annual withdrawal from storage above Topeka necessary to assure that municipal and industrial water supply requirements will be met is estimated to be of the order of 100,000 acre-feet by 2060. It is expected that the available flows will fall short of water supply needs by about 1990.

Small Communities and Rural Areas Below Topeka. Water supply needs in the smaller communities and rural areas below Topeka are estimated to reach 40 mgd by 2060. Most of these supplies will be taken from local streams or wells, rather than from the Kansas River, so no provision for these needs is necessary in the Milford Reservoir, except insofar as consumptive use affects downstream needs.

Lawrence. Present water use amounts to 4.7 mgd. The present capacity of the Lawrence water supply system is 11.0 mgd, a portion of which is from shallow wells in the Kansas River Valley. Future water supply needs for municipal and industrial purposes are estimated to reach 110 mgd by 2060. Summer use is expected to reach 130 mgd.

Water supply storage will be needed beginning about 2025. By 2060 an annual regulation of the order of 75,000 acre-feet will be required to assure that water supply needs will be met.

Kansas City, Kansas, and Surrounding Area. The present capacity of the Kansas City, Kansas, supply is 50 mgd. In 1956, the water use of the municipal system amounted to 26 mgd, but was withdrawn from the Missouri River. Since it is anticipated that Kansas City, Kansas, will continue to use the Missouri River as a source, its needs have not been further evaluated.

The suburban areas south and west of Kansas City are growing rapidly and are expected to increase from a present population of 163,000 to a population of 850,000 by 2060. The Water District No. 1 of Johnson County now serves communities in northeastern Johnson County and in adjacent areas of Wyandotte County. At the present time water is obtained from well fields in the Kansas River alluvium or is purchased from Kansas City, Missouri, and Kansas City, Kansas. In the latter case, it is supplied from the Missouri River. The Water District is currently considering additions to its own wells in the alluvium of the Kansas River Valley or a water intake in the Kansas River. Water use now amounts to an estimated 11 mgd. The Water District has estimated that use will increase to 21 mgd by 1975. It is estimated that total water use in the suburban areas and by industries securing water from the Kansas River or from wells is currently in the order of 28 mgd; this estimate is based on population and employment figures and unit water use applicable if adequate supplies and distribution systems were available. Actual use may be restricted by inadequate distribution systems at this time.

Requirements from the Kansas River are heavily dependent on the future service area of the Kansas City, Kansas, water system. Extension of the Kansas City system throughout the metropolitan area could drastically change water supply needs. Based on the current pattern of development of water supply service, municipal and industrial water use by the Water District No. 1 of Johnson County and other similar organizations or municipal systems in the area surrounding Kansas City, Kansas, and by industries located in the Kansas River Valley is estimated to reach 288 mgd by 2060. A substantial portion may be drawn from ground water sources recharged by the river, but

the major part will most likely come directly from the Kansas River if the quantity and quality are assured by upstream storage and flow regulation. It is estimated that provision for storage will be needed to assure projected water uses by about 1990. By 2060 water releases from storage totaling 210,000 acre-feet are estimated to be necessary, in addition to flows available at the 98 percent probability level, to assure projected water use.

VII. WATER QUALITY CONTROL

Present

The quality of the Kansas River is seriously affected by mineral pollutants of natural and agricultural origin and by organic waste from municipal and industrial sources.

Mineral Pollutants

Previous reports of the Public Health Service[1] and the Kansas Water Resources Board[16] indicate that chloride and sulfate concentrations in the Kansas River have been, at times, in excess of the limits recommended in the Public Health Service Drinking Water Standards[52] of 250 mg/l for each of these constituents.

The primary sources of mineral constituents in the Kansas River are weathering of rocks and soils, salt springs and seeps, and salt marshes in the drainage area west of Junction City. The concentration of mineral constituents is also increased by reservoir evaporation and evapotranspiration, leaching, and increased weathering associated with agricultural usage. While oil field brines have constituted a serious source of mineral pollution in the past, brine disposal is now considered to be under control by the Kansas Water Resources Board.[44] In 1961, records of the State Department of Health indicated that 99.9 percent of the brine produced in the Solomon and Saline River Basins was disposed of underground. However, evaporation ponds still receive about 40,000 pounds of salt per day, which constitutes a potential hazard to the water resources of the basin. Effective control of oil field wastes is required as a basis for flow regulation to be provided for water quality control in Milford Reservoir under provisions of the Federal Water Pollution Control Act.

The Kansas Water Resources Board[50] has estimated that 160,000 pounds of chloride are discharged per day from the Solomon River and 300,000 pounds per day from the Saline. No estimate of the sulfate contribution is available at this time. Estimates indicate that the average concentration of chloride in irrigation return flows in the Smoky Hill River Basin below Kanopolis, Wilson, and Glen Elder Reservoirs after full irrigation development will be 1,050 mg/l, whereas the concentration of sulfate will be 620 mg/l. An

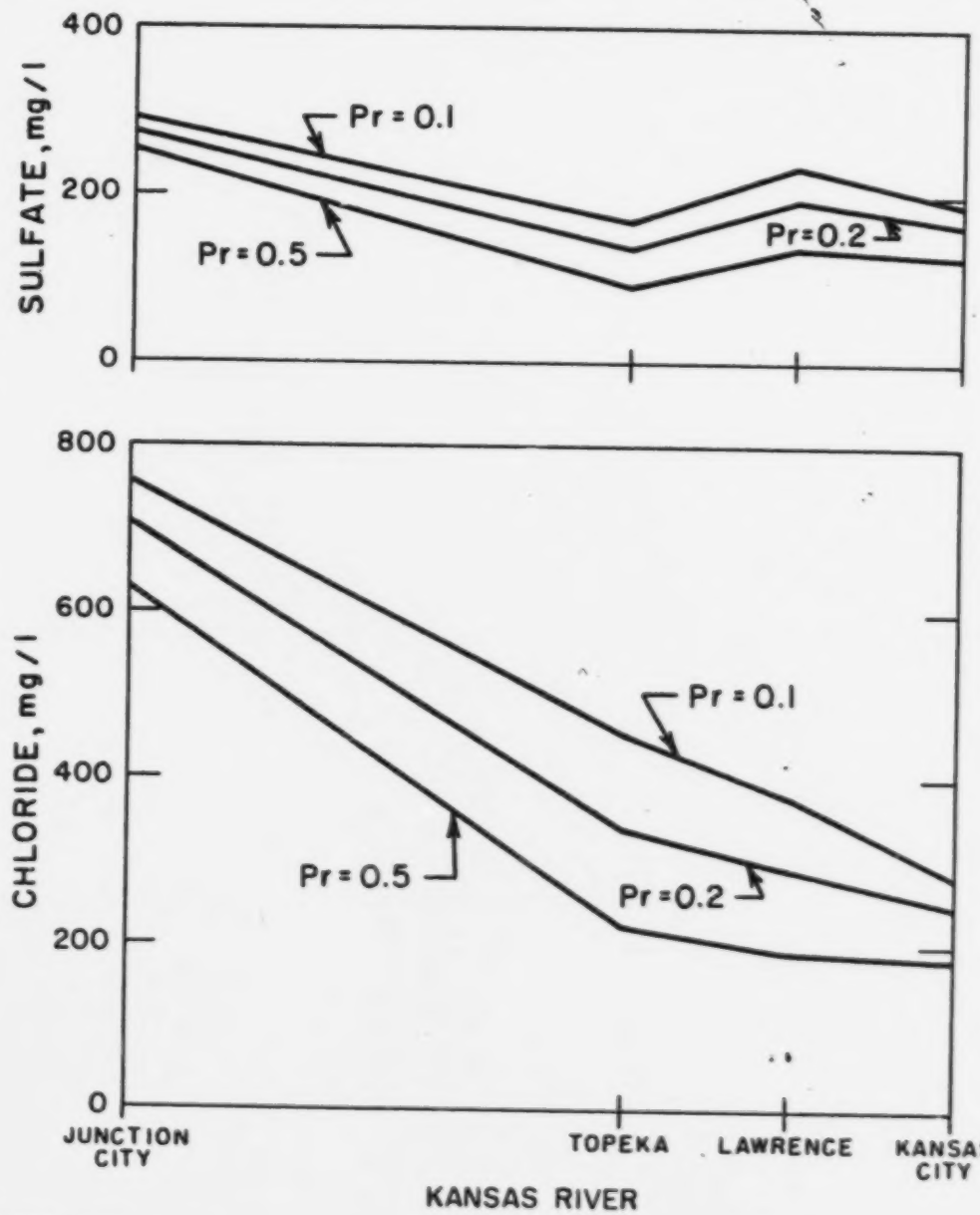
estimated 680 mg/l of the chloride will be due to weathering and solution associated with irrigation practice, which is expected to result in an increased load of 230,000 pounds per day if projected irrigation develops. The remainder is the result of concentration of minerals originally in the water as a result of evapotranspiration. These waste loads should be subject to little change except as greater or lesser irrigation application results in changes in the dilution afforded the relatively constant load and leaching is affected by increased land under cultivation.

Information supplied by the Kansas State Department of Health indicated that no oil refineries or salt plants that might be major sources of chloride ion are in operation in the Kansas River Basin from Junction City to above Kansas City at this time. Two industrial plants are known to discharge up to 20,000 pounds of chloride per day. Since water supplies in the Kansas River Basin are relatively hard, many individual supplies are softened by ion exchange and salt is used as the regenerating chemical. This undoubtedly constitutes a source of the chlorides added in the Kansas River Valley. Industrial softening is reported to be by the lime-soda process. Three chemical plants between Topeka and Bonner Springs have been estimated to discharge as much as 198,000 pounds of sulfate per day. This contribution is the basis for the increase in sulfate noted between Topeka and Lawrence in Figure 8 and has been considered separately in the determination of needs for water for quality control.

Estimates presented in Table 2 are based on releases from existing reservoirs, augmented with the records of discharge weighted annual means at proposed reservoir sites. The estimates include adjustment to 1962 conditions of upstream water resource development and evaporation losses. Changes in upstream water use and management will modify the analysis to some degree.

The coefficient of variation at Kanopolis Reservoir was used to approximate the variation to be expected at Wilson and Glen Elder Reservoirs. Since Tuttle Creek Reservoir has not regulated streamflow to the degree for which it is designed, its impact on mineral quality can not be appraised from the records. Nevertheless, the variation in annual mean concentrations of mineral constituents in the Big Blue River is very small, indicating even less variation with impoundment. This small variation is also typical of the Delaware River at the Perry Reservoir dam site.

Although these reservoirs are large, possess a high degree of regulation efficiency, and will accomplish considerable mixing, the quality of releases from existing reservoirs has been observed to vary seasonally. Table 3 shows the concentrations of chloride and sulfate in releases from Kanopolis and Harlan County Reservoirs as percentages of the annual mean concentrations. Table 3 also shows that the mineral concentration is



NOTE: ANNUAL MEAN CONCENTRATIONS INDICATED ARE EQUALED OR EXCEEDED UNDER PRESENT CONDITIONS WITH THE PROBABILITIES SPECIFIED.

WATER RESOURCES STUDY
KANSAS RIVER BASIN - KANSAS
MILFORD RESERVOIR REPORT

ANNUAL MEAN CONCENTRATION OF CHLORIDE AND SULFATE IN DEPENDABLE UNCONTROLLED FLOW

DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VI KANSAS CITY, MO.

30-a

FIGURE 8

Table 2

Estimated Annual Mean
Mineral Concentration in Reservoir Releases
Milford Reservoir Study

Reservoir	Ion	Mean Concentration mg/l	Standard Deviation of the Mean, mg/l
Kanopolis	Cl	200	60
	SO_4	210	50
Wilson	Cl	430	100
	SO_4	250	50
Glen Elder	Cl	70	20
	SO_4	130	40
Milford			
Before Impoundment	Cl	40	5
	SO_4	90	20
After Impoundment	Cl	30	10
	SO_4	60	10
Tuttle Creek	Cl	30	5
	SO_4	40	10
Perry	Cl	20	5
	SO_4	70	10

Table 3

Typical Seasonal Differences
in Mineral Concentration in Reservoir Releases
Milford Reservoir Study

	Ion	Percent of Mean Annual Concentration			
		Oct.-Dec.	Jan.-Mar.	Apr.-June	July-Sept.
Kanopolis	Cl	103	124	103	70
	SO_4	112	120	98	70
Harlan County	Cl	110	115	96	78
	SO_4	104	109	99	88

maximum during the January-March quarter after summer flows have mixed with reservoir contents and is minimum during the July-September quarter following spring floods. The range at Harlan County is less than at Kanopolis because of the hydrogeochemical difference in the drainage areas and because more reservoirs and other water retarding and mixing structures have been constructed in the Republican River Basin than in the Smoky Hill River Basin. Discharge of the contents of any remaining evaporation ponds during high flow would contribute to total mineralization, but would be counter to the seasonal pattern described above.

Based on the similarity of the hydrogeochemical character of the drainage areas, the seasonal distribution of reservoir quality at Kanopolis has been applied to the future releases from Wilson and Glen Elder Reservoirs and the pattern of water quality at Harlan County Dam has been applied to releases from Milford Dam. These releases or associated irrigation return flows are considered as the dependable controlled flow.

Probable annual mean concentrations of chloride and sulfate in the runoff are shown in Figure 8. Typically, the monthly mean chloride concentration varies from about 50 percent of the annual mean concentration in July to 160 percent in January. Sulfate is a little more variable, and ranges from about 35 percent of the annual mean concentration in July to 180 percent in December.

The data in Tables 2 and 3 and Figure 8 have been used in the computation of water quality control needs, although it is pointed out that the figures presented are only approximations of the actual concentrations to be expected in any particular season. Kanopolis Reservoir is thus seen to be quite inefficient as an alternate source of dilution water because of its concentration of chloride and sulfate. Releases from Wilson Reservoir could actually aggravate rather than alleviate mineral quality problems in the Kansas River. Waters from Tuttle Creek and Perry Reservoir are of much higher quality and are therefore much more useful for stream quality control. The quality of Milford Reservoir discharges will be nearly as good for stream maintenance as the quality of discharges from Tuttle Creek and Perry Reservoir.

Mineral additions from domestic and incidental industrial use were estimated and added to the Kansas River at the various points of use. An average chloride contribution of 10 grams per person per day was estimated based on a review of physiology handbooks. Available data include that substantial quantities of chlorides are discharged in municipal wastes but that a total discharge of 40 grams per person per day is representative of normal waste discharges in a moderately industrial community. A similar analysis for sulfates indicates that the average individual contribution was 2.5 grams per person per day, while an industrial community might discharge 15 grams per person per day.

The mineral additions resulting from municipal and industrial use are small in comparison to the large natural sources and irrigation but have been considered in calculations in this report.

Organic Wastes

Municipal and industrial wastes constitute the major organic waste loads discharged into the Kansas River. Data on municipal and industrial wastes discharged in 1956 are presented in the reports of the Kansas Water Resources Board.[16] Loads discharged in 1957 are included in the Public Health Service Inventory of Municipal and Industrial Waste Facilities[19] which is currently being updated. Additional information was secured from the data sheets prepared by the Kansas State Department of Health.

Primary sewage treatment is provided at Junction City, Manhattan, Lawrence, and most of the smaller communities discharging directly into the Kansas River. Secondary treatment is provided for most of the wastes from Topeka and many of the suburban communities near Kansas City. Kansas City, Kansas, does not have treatment at this time, but is in the process of providing primary treatment with probably discharge of treated effluent to the Missouri River.

Streamflow regulation for quality control is provided only when adequate treatment of municipal and industrial wastes will not assure acceptable quality conditions in the stream. Adequate treatment has been administratively determined to be secondary treatment for municipal wastes or its equivalent in terms of waste reduction, control, and treatment for industrial wastes. The population equivalent of present municipal and industrial waste loads discharged to the Kansas River after provision of secondary treatment are estimated below:

	Municipal	Industrial	Total
Junction City	3,800	800	4,600
Manhattan	4,400	800	5,200
Small Communities and Rural Areas Above Topeka	12,000	3,200	15,200
Topeka	20,800	11,200	32,000
Small Communities and Rural Areas Below Topeka	12,000	3,200	15,200
Lawrence	10,400	11,200	21,600
Suburban Kansas City	7,000	14,000	21,000
Total	70,400	44,400	114,800

Present organic waste discharges from municipal and industrial sources are based on 0.25 pounds of ultimate first-stage biochemical oxygen demand (BOD) per person per day in a nominal waste flow of 100 gpcd. Additional flow was assumed to represent commercial and industrial usage. While not presently provided at all communities, an 80 percent reduction in estimated

organic waste loads has been considered reasonable for determining present water quality control needs.

Industrial water use and waste discharges are not now well defined.[16] Sufficient, recent, detailed information is not available to enumerate existing industries. The additional industrial waste load has been approximated by assuming all industrial wastewater discharges (exclusive of cooling water) to have a residual concentration of organics comparable to the residual after adequate treatment of domestic sewage.

For the purposes of this report, it is assumed that these totals represent the entire municipal and industrial waste contributions to the Kansas River or its tributaries after adquate treatment has been provided as required in the Federal Water Pollution Control Act for consideration of streamflow regulation needs. The Kansas Water Resources Board and the Kansas State Department of Health are carrying on an active program of water resource development requiring treatment of municipal and industrial wastes. Assurances should be obtained from these agencies that adequate treatment of waste effluents will be required of municipalities and industries discharging wastes to the Kansas River.

Water Quality Objectives

The quality of water determines the uses that can be made of it, and unless the quality is maintained to a reasonable extent, possible economic benefits of its use will be lost and the public health may be endangered.[7,11,14] Withdrawal and instream uses determine the water quality objectives applicable to a stream. The objectives used in evaluating quality conditions in the Kansas River have been based on the limited length of stream available for recreational use in Kansas and its use as a source for raw water by communities along its banks. Until fairly recently, major emphasis was placed on the problem of sewage pollution, initially because of the relation to water-borne enteric disease and later because of the effects of organic pollution on streams and aquatic life. As areas became increasingly industrialized, the contribution of water-borne industrial wastes has grown in importance.[11] Natural mineralized flows and land runoff, especially from irrigated agriculture, may also adversely affect the quality of streams.

The objectives used in evaluating quality conditions in the Kansas River have been based on a consideration of the objectives, standards, and criteria which have been applied by various State and interstate agencies and have been used by the Public Health Service in the past in evaluating pollution conditions.[14] The primary responsibilities and rights of the States in preventing and controlling water pollution within their boundaries, as set forth in the Federal Water Pollution Control Act, have been the basis for placing particular emphasis on the standards of quality that have been established by the Kansas State Department of Health.

In setting water quality objectives for streams for the protection of aquatic life, mere survival is not enough, and the minimum level accepted should be suitable for the continuous maintenance of satisfactory fish life and fish food organisms. Objectives are therefore based on the environmental requirements of the fish species present in the stream. Tests by the Public Health Service have indicated that for a well-rounded warm water fish population, dissolved oxygen concentrations should not be below 5 mg/l for more than 8 hours of any 24-hour period and at no time below 3 mg/l.[15] Based on these considerations, and on the limited number of perennial streams available in the area, a dissolved oxygen objective of 5 mg/l has been selected for purposes of this report to maintain aquatic life and to assure present and and anticipated recreational use of the stream. In a recent State of Kansas study of recreation it was concluded that recreational use of the Kansas River and other streams in the State will become increasingly important. Purchase of easements to assure public access is under consideration.

Interstate enforcement activities of the Public Health Service have given considerable emphasis to bacterial pollution. The Manual of Recommended Water Sanitation Practice of the Public Health Service[2] recommends that coliform densities in raw water supplies not average more than 5,000 per 100 ml in any month nor be in excess of this figure in more than 20 percent of the samples or in excess of 20,000 per 100 ml in more than 5 percent of the samples in any month, even when coagulation, filtration, and postchlorination are provided. For instream recreational use even lower levels are considered desirable. Considering the limited water contact recreational use of the Kansas River and natural purification between points of waste discharge and subsequent water use, the objective used in the present report is that the concentration of coliform bacteria not exceed 5,000 per 100 ml at controlled flows.

The Public Health Service Drinking Water Standards[52] recommends that the concentrations of chlorides and sulfates not exceed 250 mg/l in finished waters. While water having higher concentrations is being used in Kansas and in other States when no other water is economically available, such use is not considered desirable. Higher concentrations are acceptable for irrigation use but lower values are considered desirable for certain industrial uses. Where water treatment must be provided fluctuations in water quality are undesirable. Since neither constituent is removed by normal water treatment processes, the finished water objectives have been applied to the Kansas River where it is used as a water source.

Potentially toxic materials from industrial processes should be limited to the levels set forth in the Public Health Service Drinking Water Standards.[52] Numerous chemicals used for insect control, weed control, and other agricultural purposes have been developed in recent years. Since these chemicals are often extremely toxic to aquatic life and constitute a potential hazard to humans,

their concentration should be limited in the river to protect aquatic life and at river water intakes to protect municipal users. However, available data are inadequate to established minimum levels for separate constituents. As a general limitation on such materials the last revision of the Public Health Service Drinking Water Standards recommended that carbon chloroform extractables in finished water be limited to C.2 mg/l. With development of the chemical industry, the particular chemicals may change radically so that continual evaluation will be necessary.

The responsibility for controlling water pollution in the State of Kansas resides with the State Department of Health. Permits are required for discharge of both municipal and industrial wastes into the waters of the State.

The criteria established for the Kansas River Basin in 1950[3] are as follows:

> "The Kansas State Board of Health, after giving careful consideration to the data collected and its responsibilities, is adopting the following policy which is believed to be in the best public interest. This policy will apply to sewage and industrial, organic or inorganic pollution throughout the Kansas River Basin.
>
> 1. That at minimum stream flows the biochemical oxygen demand exerted on any one section of a stream shall not reduce the dissolved oxygen content below 5 parts per million.
>
> 2. That at minimum stream flows the goal for coliform bacteria is 20,000 organisms or less per 100 milliliters (this quality should not be confused with the number of coliform organisms present during heavy runoff, since at such a time they may be primarily soil organisms not indicative of sewage pollution).
>
> 3. That the primary treatment of sewage is the minimum amount which will be acceptable.
>
> 4. Where oil pollution is concerned, all above-ground oil storage tanks shall be surrounded by an earth dike with a capacity equal to the contents of the tank plus a free board of 1.5 feet.
>
> 5. All brine ponds and waste oil ponds shall be operated in such a manner that 2.5 feet is provided above the maximum brine level.

6. That no brines from any field in the river basin shall continue to be stored in ponds, or discharged directly or through seepage to a fresh water course, either surface or subsurface, after July 1, 1951,...."

Criteria applicable to certain reaches of the Arkansas River are similar except that a minimum D.O. of 4 mg/l is allowed and industrial wastes should be made substantially free of toxic substances before discharge to a water course.

The objectives used in this study for evaluating flow requirements and consequent storage needs are consistent with those of the State of Kansas. The maintenance of adequate water quality is considered to be an important factor in continued economic growth in the Kansas River Valley.

Future

Flow regulation is necessary to assure that the quality of water in the Kansas River meets the selected objectives for dissolved oxygen content and mineral content. Regulated flows and storage drafts needed have been estimated.

The bacterial quality of the Kansas River does not meet the objective established for this report in certain reaches at this time. Since it is considered possible to meet the objective by a combination of secondary treatment and postchlorination, no consideration has been given to dilution flows for this purpose.

Milford Reservoir

The flow of the Republican River near its mouth is a variable mixture of uncontrolled runoff, irrigation return flows, and Harlan County and Lovewell Reservoir releases unused for irrigation. Milford Reservoir will provide considerable mixing and is expected to significantly reduce the annual mean concentration of chloride and of sulfate in Republican River flows near Junction City in spite of the loss of water by evaporation from the reservoir surface. As indicated on Table 2, the decrease in chloride and sulfate concentrations will probably be in the order of 30 percent.

The dissolved oxygen content of the discharges from Milford Reservoir will depend on the quality changes taking place within the reservoir, whether stratification develops and, if so, on the elevation from which water is

withdrawn. The economic base study shows that the lower Republican River area (Subarea 1) has lost population since 1910 and now has a population of 53,740. Much of the loss has been associated with the increased mechanization of agriculture. On the basis that the predominant industry above Milford Reservoir is and will continue to be agriculture, little population change is expected in the foreseeable future. With adequate treatment, the domestic wastes presently discharged are not expected to adversely affect the quality of water in the reservoir. Agricultural drainage can contribute organic residues and nutrients from the soil, or from applied fertilizer, to the stream.

When present in sufficiently high concentrations, nutrients can stimulate considerable algal growth as a result of photoshythetic activity. The decay of dead cells and oxidation of organic wastes in the inflowing water can cause a reduction in the oxygen concentration and taste and odor problems in lakes and reservoirs. This is especially serious when thermal stratification develops and withdrawal of water is from near the bottom of the reservoir as is planned in Milford Dam.

To avoid the possibility of low dissolved oxygen discharges it is often recommended that multilevel outlets be provided to facilitate selecting the best quality water for discharge. The concentration and effect of nutrients entering Milford Reservoir can not be estimated at this time, but no adverse dissolved oxygen conditions have been reported in or below the nearby Harlan County Reservoir. The persistent winds and relatively low shore line around reservoirs in the vicinity of Milford Reservoir have been suggested as the reason that stratification has not been observed. It is therefore concluded that adverse dissolved oxygen conditions are not likely to occur below Milford Dam. If subsequent observation indicates that dissolved oxygen levels below the quality objective are developing in the discharge, appropriate corrective measures will be needed.

Mineral Wastes

Future requirements for control of mineral quality depend largely on the amount of evaporative loss in reservoirs, consumptive use in agriculture, consumptive loss in municipalities and industries, and evaporative loss induced by power production. As a basis for analysis it is assumed that reasonable efforts will be made to minimize mineralization of irrigation return flows and that any industry producing large mineral waste loads will be required to provide adequate waste handling facilities as has been required of the oil extraction industry.

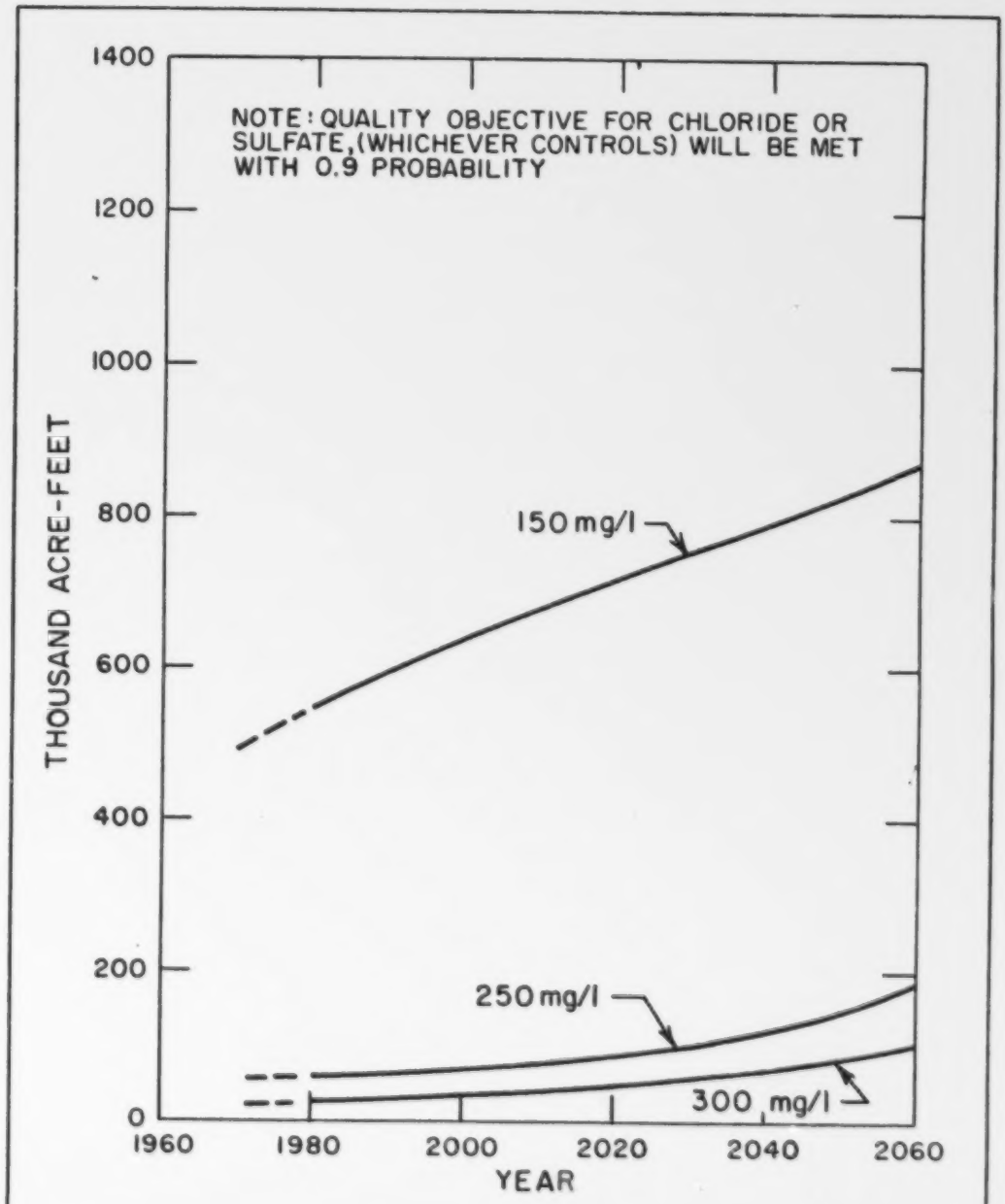
The annual storage drafts from Milford Reservoir required to maintain chloride and sulfate concentrations at or below 150, 250, and 300 mg/l are shown in Figure 9. The indicated draft on storage would provide 90 percent protection against excessive concentration during any year at Topeka and Kansas City. Figure 9 indicates that regulation requirements increase rapidly if concentration objectives are made more restrictive. The required draft on storage in the early years of project development are tentative since they depend on the rate of irrigation development.

The draft on storage needed from Milford and/or other reservoirs to maintain a mineral quality that meets the selected objectives would be reduced if the protection level were reduced to 80 percent as shown in Figure 10. In view of the potential economic development and population growth in the study area, protection at the 90 percent level has been selected as the basis for analysis in this report.

Typically, streamflow regulation for mineral quality control is required in the winter period, October through March, with the maximum demands in December and January. At Junction City, the quality of water withdrawn directly or indirectly from the Republican River will improve its construction of Milford Dam, as indicated in Table 2. Since Junction City uses the Republican River for its water supply and even under present conditions does not have mineral concentrations in excess of the objectives selected, no regulation to maintain mineral quality is needed there.

Conservation storage planned for Milford Reservoir is not sufficient to provide full control of mineral quality in the Kansas River. The quality of the Kansas River above the confluence of the Big Blue River will therefore be below the mineral quality objectives for considerable periods of time even after dilution of Smoky Hill River flows by releases from Milford Reservoir. As shown in Table 2, the Big Blue River is of excellent mineral quality. It is therefore expected that Manhattan will use the Big Blue River as its water supply source, with provision for water supply storage in Tuttle Creek Reservoir, if necessary, rather than depend on the Kansas River.

Since Topeka uses water from the Kansas River, provision of sufficient dilution to assure that the mineral quality objectives are met there and to the confluence of the Kansas River with the Missouri River would improve the water supplies of Topeka, Lawrence, and suburban Kansas City, Kansas, as well as make available better quality water for the smaller communites and manufacturing plants along the banks of the river. The limited withdrawal use of the Kansas River between Junction City and Manhattan is not felt to justify efforts to control mineral quality in that reach. However, control of quality further downstream will result in



WATER RESOURCES STUDY
KANSAS RIVER BASIN - KANSAS
MILFORD RESERVOIR REPORT
ESTIMATED ANNUAL DRAFT ON STORAGE TO MAINTAIN CHLORIDE AND SULFATE QUALITY OBJECTIVES AT THREE LEVELS

DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VI KANSAS CITY, MO.

FIGURE 9

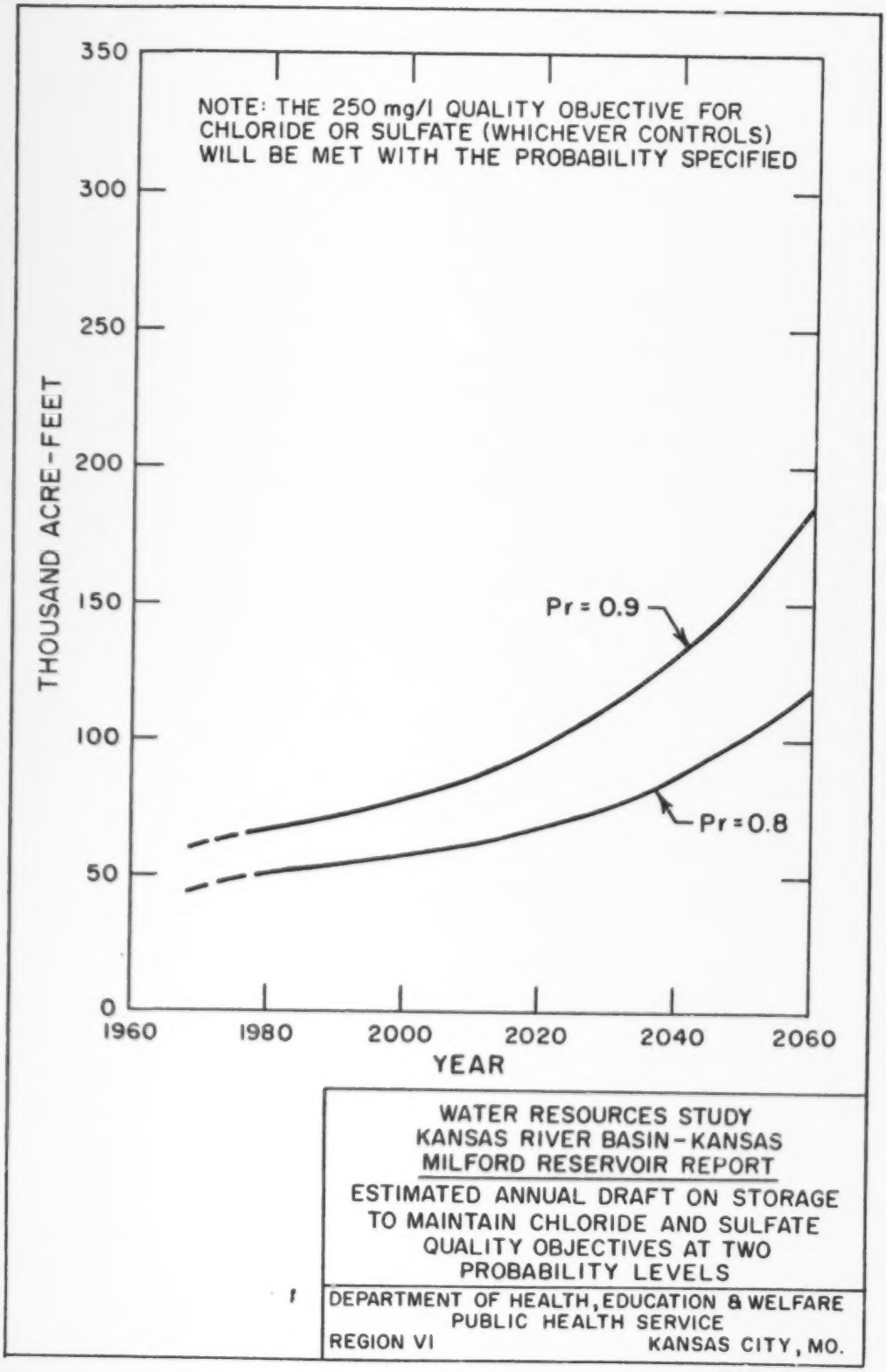


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FIGURE 10

substantial improvement in quality between Junction City and Manhattan and essentially complete control below the confluence of the Big Blue River. Dilution could also be secured from diversion of flows from Perry Reservoir on the Delaware River and from utilization of storage in the Vermillion River and Soldier Creek. In the future, it may be considered more desirable to use the higher quality water available in these tributary streams directly for municipal water supply, rather than to use the Kansas River since it will be near the quality objectives, the minimum quality considered acceptable for domestic use, for considerable periods of time.

Regulation by Perry Reservoir was previously considered for water quality control. Storage on Soldier Creek and the Vermillion River is currently being considered for water supply in the Corps of Engineers review report on the Kansas River.[24] However, since that report was issued prior to passage of Public Law 87-88, either direct water supply withdrawal or dilution of high mineral concentrations in the Kansas River could have been contemplated. Flow regulation needs have been estimated to assure that concentrations of chloride or sulfate will not exceed 250 mg/l in the flows of the Kansas River at Topeka and, considering regulation by Perry Reservoir, at Kansas City. Need for flow regulation will increase rapidly with the development of irrigation on the Smoky Hill, Saline, and Glen Elder Projects. By 1980 a draft on storage of about 70,000 acre-feet will be needed to assure that mineral quality standards will be met at Topeka in 90 percent of the years. Additional expansion of irrigation and increasing population and industrial development will result in a further increase to about 190,000 acre-feet by 2060. As previously noted, the estimated regulation requirements include a 25 percent allowance to cover such items as synchronization of reservoir releases with downstream needs, conveyance losses, atypical flow or quality conditions, and unforeseen pollution.

Flow regulation by Perry Reservoir will be sufficient to meet mineral quality objectives at Lawrence and suburban Kansas City until about 1970. After that time, the draft on storage needed from Milford or other reservoirs will increase gradually to 190,000 acre-feet to assure adequate water quality through 2060.

Organic Wastes

Present experience indicates that in most built-up areas of the United States, essentially the entire population will need to be served by sewer systems discharging through treatment plants.[33] It has been assumed that this will be approached over the design period in the Kansas River Basin, and estimation of flow regulation storage needs has been based on the collection of municipal and industrial wastes to the maximum extent possible,

provision of secondary treatment for organic wastes or other methods of controlling waste at the source, and discharge of treatment plant effluents to the Kansas River or its tributaries.

With better collection of wastes and increasing emphasis on water quality, gradual improvement in waste collection and treatment can be expected. In this report the following municipal waste treatment efficiencies and resultant ultimate BOD of waste discharges have been used:

	1960	1980	2010	2060
Reduction, %	80	85	90	90
Ultimate BOD of Discharge, mg/l	60	45	30	30

Based on the above and on estimated populations in each of the major water use areas, the residual waste loads that will be discharged to the Kansas River or its tributaries have been estimated, as shown in Appendix G. These results indicate the probable order of magnitude of residual waste for which provision of streamflow regulation will be needed.

The quantity of water required below the various major waste sources has been based on the volume of waste discharged, the expected BOD level of the waste and of the Kansas River, estimated deoxygenation and reaeration factors, and temperature. The residual waste from upstream sources, uncontrolled surface drainage from urban and rural areas, and from storm water overflow was assigned a conservatively high value of 5 mg/l (ultimate) as reflected in the initial load above the waste outfall.

The summer season (June, July, and August) flows in cubic feet per second required below major water use areas, including return flows, to assure that dissolved oxygen objectives are met have been estimated as tabulated below:

	1960	1980	2010	2060
Manhattan	30	45	75	170
Topeka	175	290	450	1000
Lawrence	100	150	270	630
Suburban Kansas City	125	300	585	1690

Flow requirements will vary throughout the year depending on temperature and waste loads. Seasonal requirements, estimated as a percentage of the summer season flow requirements, are tabulated below:

	1960	1980	2010	2060
Summer (June, July, and August)	100	100	100	100
Spring and Fall	75	65	60	60
Winter (December, January, and February)	40	40	35	35

Flows needed will vary from year to year and during short periods, depending on temperature conditions and actual waste discharges; but these flows are considered reasonable for estimating storage requirements for flow regulation purposes. Greater precision in the calculation of water quality control flows will be possible when detailed data on the Kansas River and on industrial waste sources in the study area are available from the comprehensive water supply and water quality control studies planned by the Public Health Service in the near future.

Minimum flows generally occur in the winter months when dilution requirements for assimilation of residual organic wastes are lowest and the dissolved oxygen saturation levels are highest. However, the "Kansas River Basin Water Pollution Investigation" report[1] showed low flows in the summer season (June, July, August, and September) to be almost as low as the winter flows and in some cases lower. The "minimum streamflow" for assimilation of organic waste treatment plant effluent has been interpreted as the 30-day mean low flow occurring once in 10 years,$_{50}$ based on discussions with the Kansas Department of Health and the Kansas Water Resources Board. The draft on storage needed to regulate streamflow has been estimated from differences between monthly flows and the seasonal water supply and quality control requirements for the larger municipalities of the Kansas River Valley.

On the basis of the anticipated organic waste loads, flow regulation for control of water quality, as measured by dissolved oxygen, will be needed beginning about 1990. Figure 11 shows that by the end of the design period an annual draft on storage of 150,000 acre-feet will be required to assure that residual organic wastes can be assimilated in 9 years out of 10 without depletion of dissolved oxygen below 5 mg/l. With streamflow regulation the dissolved oxygen concentration will be above the objective in most years.

Water quality control needs for organic waste assimilation in the individual water-use areas of the Kansas River Valley are discussed below:

Junction City. On the basis of organic pollutants expected to be discharged to the Kansas River after treatment at their source, flow regulation for quality control could become a factor at Junction City by about 2040. However, if the increased sustained flow that will result from return flows from irrigation below Kanopolis, Wilson, and Glen Elder Dams is considered, adequate flow should be available to receive residual wastes when it is needed.

Manhattan. Streamflows necessary to assimilate the organic waste discharges from Manhattan are expected to be available below the confluence of the Big Blue River. With increased minimum flows resulting from irrigation in the Smoky Hill drainage area, dissolved oxygen conditions should be still further improved.

Small Communities and Rural Areas. The smaller communities in Subarea 6 will discharge wastes at widely scattered points and, in most cases, to tributary streams of the Kansas River. Flow regulation may be needed to maintain water quality in tributary streams below some of these communities. However, it is not anticipated that additional storage will be required to maintain the quality the Kansas River as a result of the wastes from the smaller communities.

Topeka. The expansion of governmental offices and functions and increased industrial activity in the Topeka area will greatly increase the waste load eventually reaching the stream even with municipal waste treatment now considered adequate and with equivalent reduction of industrial wastes by treatment or control at their sources. It is estimated that flow regulation will become necessary by about 1995. Since flow regulation needs at Topeka are smaller than at Kansas City, maintenance of required flows at the latter point should assure that water quality at Topeka is satisfactory.

Lawrence. Although municipal and industrial growth is expected over much of the valley between Topeka and Kansas City, Lawrence will probably remain smaller than Topeka. Flow regulation for water quality control probably will be needed at Lawrence by about 2025. Flow regulation needs are smaller than at either Topeka or Kansas City so that maintenance of required flows at the latter point should assure that water quality at Lawrence is satisfactory.

Suburban Kansas City, Kansas. The largest concentrated waste load tributary to the Kansas River is expected from the area south and west of Kansas City, Kansas. Plans of Kansas City, Kansas, now call for discharge of municipal and industrial wastes to the Missouri River after adequate treatment. This will result in substantial improvement in water quality near the mouth of the Kansas River. The area to the south and west is now being served by local sewer districts. In the last few years, several districts have cooperated in the construction of a large plant by Mission Township Sanitary District No. 1 in Johnson County.

In 1957, nine sanitary district in Wyandotte County were provided sewer service by Kansas City, Kansas. At that time, the estimated population served was quite small, but, with the outward growth of Kansas City, substantial waste loads will develop.

As a result of the sewerage and sewage treatment program of Kansas City, Kansas, the wastes from the major meat packing plants, having waste loads estimated to be equivalent to 50,700 P.E., will be intercepted by municipal sewers, treated by Kansas City, Kansas, and subsequently discharged to the Missouri River. The extent to which future industry will locate within the area served by Kansas City sewers has a very large bearing on the future waste loads and quality control flows needed in the Kansas River.

Future municipal and industrial waste loads to be discharged to the Kansas River in the Kansas City area have been estimated on the basis of the difference between the calculated metropolitan area loads and the calculated loads to be discharged to the Kansas City, Kansas, municipal system. Industrial development is largely within the city at the present time, but the major part of the projected future growth is expected outside the service area of the Kansas City, Kansas, sewerage system. On the basis of the anticipated organic waste loads, flow regulation for water quality control will be needed beginning about 1990, as shown in Figure 11. As waste discharges are expected to reach the Kansas River at greater distances from the mouth of the river than at present, it has been assumed that the critical dissolved oxygen condition will occur in the Kansas River. On this basis it is estimated that an annual draft on storage of 150,000 acre-feet will be required to assure that residual organic wastes can be assimilated in 9 years out of 10 without depletion of dissolved oxygen below the quality objective. With streamflow regulation the dissolved oxygen concentration at the mouth of the Kansas River will be above the objective in most years.

Extension of the Kansas City, Kansas, sewerage system to accept waste loads from major industries or from municipalities or sanitary districts beyond the service area on which this report is based could reduce future water quality control requirements. Current and prospective extension of Kansas City sewer service to outlying areas should be re-evaluated in future reports as the plans of the city become more definite.

Mineral and Organic Wastes

During some periods of each year flow regulation will serve to control both mineral quality and organic waste assimilation needs. At times, however, regulation will be needed for maintenance of dissolved oxygen and not for minerals, and vice versa. The volumes are neither completely independent nor mutually inclusive. Storage to provide a draft on storage of 210,000 acre-feet will be needed by 2060 to satisfy both aspects of quality control, as shown in Figure 12. As with the storage recommended for water supply, these volumes include a 25 percent adjustment to cover such items as synchronization of reservoir releases with needs downstream, conveyance losses, atypical flow or pollution conditions, and unforeseen requirements.

Water quality control releases should be based on frequent observations of quantity and quality of flow in the Kansas River at critical points of use throughout each season and year when such releases are needed. The stream monitoring program established by the Kansas State Department of Health may provide the data necessary to assure reasonable control of water quality, and should be used to the greatest extent possible.

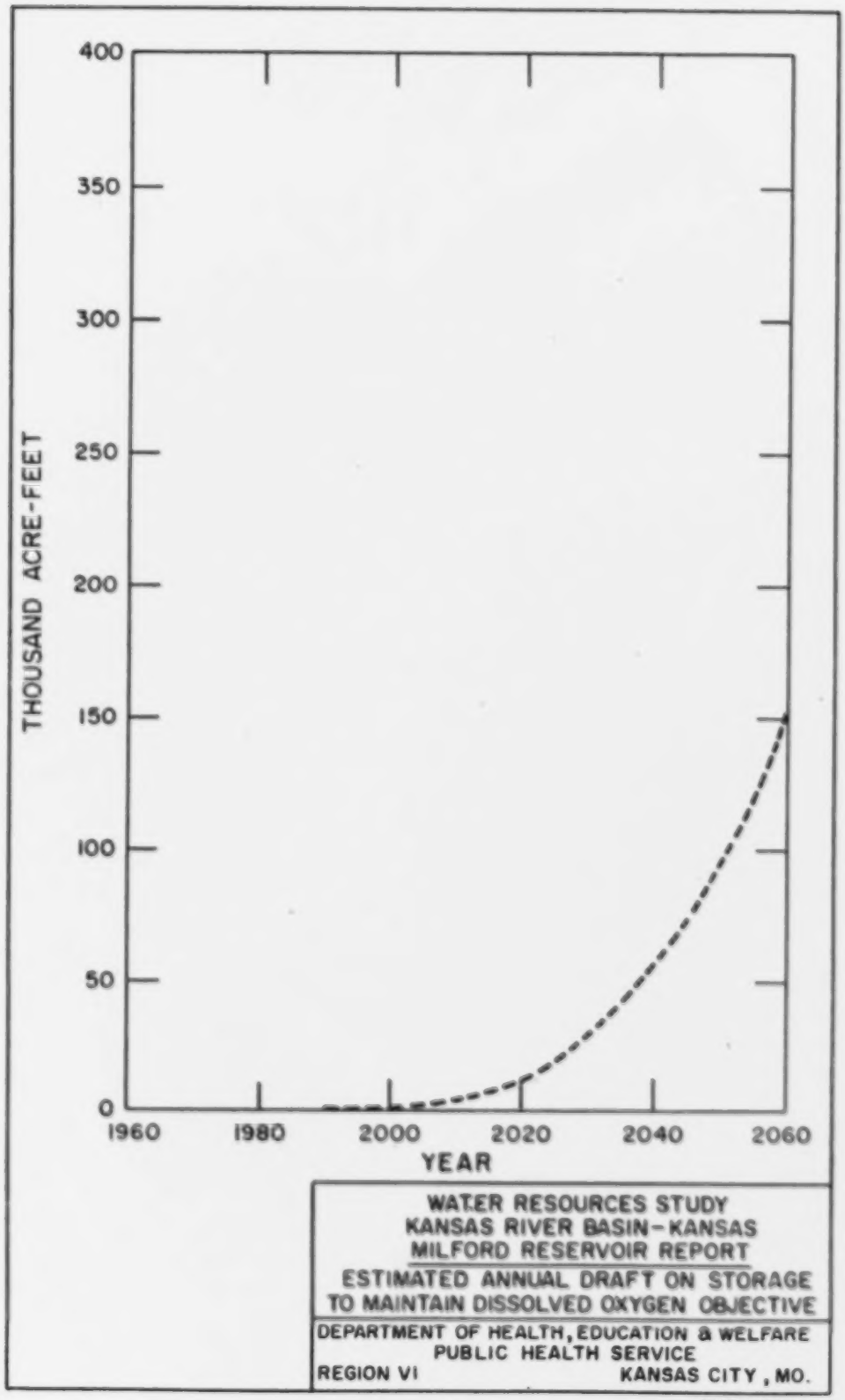

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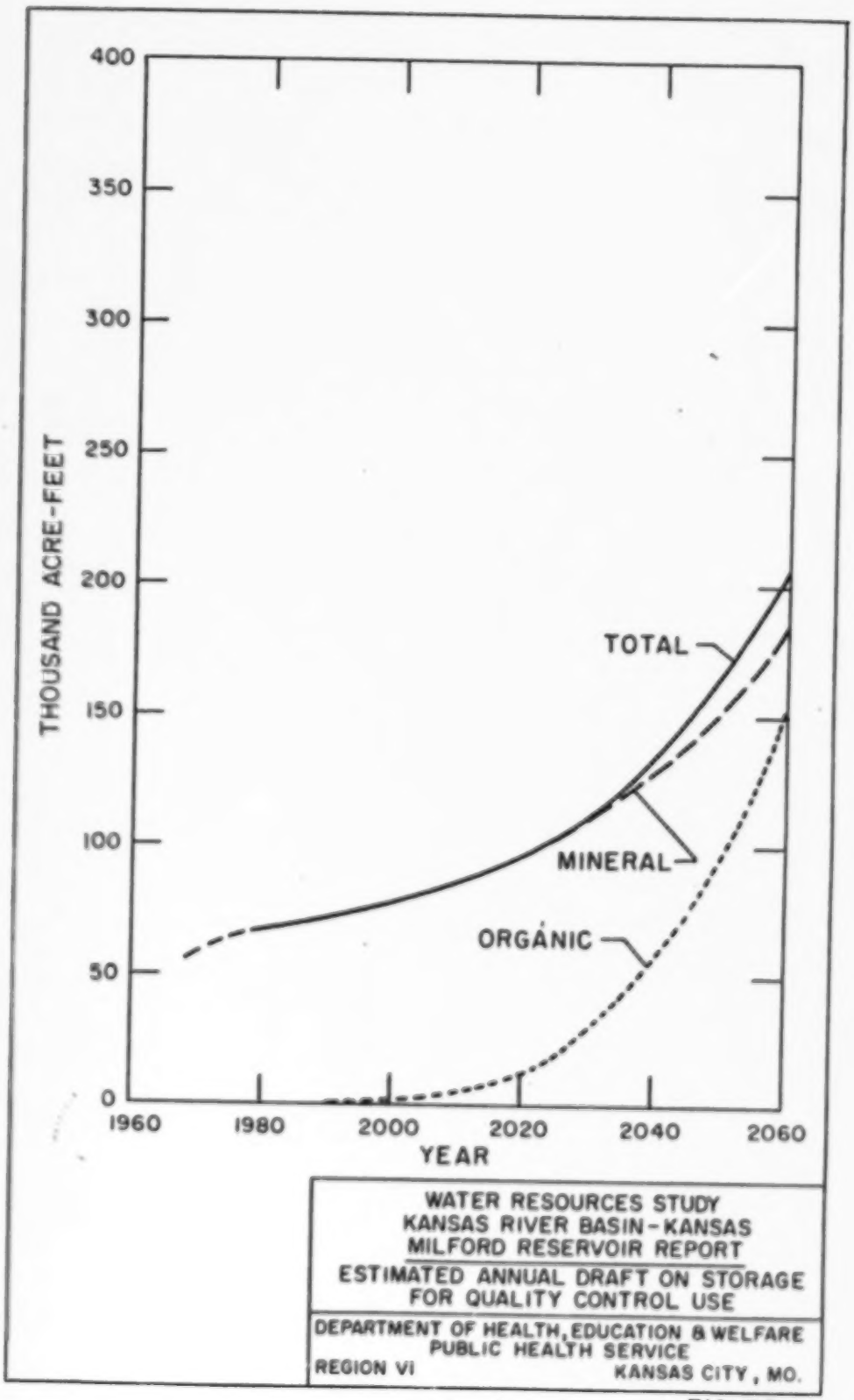
FIGURE 11


400
350
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THOUSAND ACRE-FEET
TOTAL
MINERAL
ORGANIC
1960
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2000
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2040
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YEAR
WATER RESOURCES STUDY
KANSAS RIVER BASIN - KANSAS
MILFORD RESERVOIR REPORT
ESTIMATED ANNUAL DRAFT ON STORAGE
FOR QUALITY CONTROL USE
DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VI
KANSAS CITY, MO.

FIGURE 12

VIII. BENEFITS OF STORAGE

The need for streamflow regulation for water supply and quality control purposes has been recognized in Kansas Water Resources Board publications[16,25] and in the request by the Governor of Kansas for consideration of water supply storage in Milford Reservoir under provision of Title III of the Water Supply Act. This study confirms the present need for streamflow regulation for control of mineral quality, and indicates the future need for municipal and industrial water supply and for control of the adverse effects of organic materials remaining after adequate treatment and control of domestic and industrial wastes. Provision for such flow regulation will be required in increasing amounts as population and industrial growth takes place in the Kansas River Valley.

The Big Blue River, Vermillion River, Soldier Creek, Delaware River, Wakarusa River, and several other smaller tributaries have a quality of water that is superior to that of Kansas River at the present time and probably will be of increasingly better quality by comparison with that of the Kansas River in the future even with flow regulation for quality control as estimated in this report. A study of possible uses of storage from all reservoirs that have been constructed or are being considered could develop plans for the most effective use of waters of different quality. Such a study may indicate the desirability of developing municipal supplies for Topeka, Lawrence, and suburban Kansas City, Kansas, from these tributaries rather than from the Kansas River.

A review and evaluation of the entire water resource program of the Kansas River Basin is needed so that the best use of all possible water resource projects can be considered for the greatest economic benefit to the entire basin. The water resource reports prepared by the Kansas Water Resources Board provide considerable valuable information and the Public Health Service's Lower Missouri River Basin Project should provide such comprehensive review. As water resource development progresses, the entire program should be reviewed and evaluated periodically so that additional development will be based on the best available information.

Water Supply

While water quantity is not a problem at this time, the anticipated municipal and industrial water supply needs of the Kansas River Valley will exceed the depleted flow of the Kansas River at Topeka and Kansas City beginning about 1990, which is within the design period for the Milford Project. By 2060, the end of the design period, it is expected that an average of 288

mgd and a maximum of 356 mgd (in the summer season) will be needed in the suburban Kansas City area. At the present time an estimated 100 mgd is available for water supply purposes in the Kansas River in the Kansas City area so that as much as 256 mgd will be needed to meet summer needs. A draft on storage of 210,000 acre-feet will be needed to satisfy anticipated water supply needs.

The quality of water available in the Kansas River after flow from the Republican River is mixed with that from the Smoky Hill River will meet minimum quality objectives if the suggested water supply and quality control storage is provided or if other means of quality control are developed and placed in use. Since the Corps of Engineers has estimated that Milford Reservoir will be able to sustain a draft on storage of 76,000 acre-feet per year in 98 percent of the years in addition to an estimated normal flow of 41,000 acre-feet, additional storage in other reservoirs would also be required to provide all water supply needs. Allocation of the 300,000 acre-feet of conservation storage in Milford Reservoir to domestic and industrial water supply use is estimated to have an average value of $285,000 per year, including $50,000 per year for operation and maintenance over the period the storage is needed. Municipal and industrial water supply storage is considered to be worth the cost of the most economical single-purpose reservoir having the same streamflow regulation capacity. Storage could be provided in a number of smaller single-purpose reservoirs on tributaries in the vicinity of the water use areas. The water thus made available would be of better quality than that in the Kansas River but the cost would be greater than for equivalent storage in a single-purpose reservoir at the Milford Project site. As water supply and water quality control needs grow, storage on both the Republican River and on the local tributaries will be needed. In this area and for the draft on storage required for municipal and industrial purposes, a single-purpose reservoir on the Republican River in the vicinity of the Milford Dam site is therefore considered the most reasonable alternative to provision of storage in the Milford Project. The initial cost of a 300,000 acre-foot reservoir is estimated to be $18,000,000 on the basis of average costs of reservoirs constructed by the Corps of Engineers in the project area as presented in the Senate Select Committee reports.[37] The estimate of the cost of the alternative single-purpose project should be refined by the construction agency in final project evaluation. Project costs were amortized over a bonding period of 30 years at 4 percent interest. The annual payments over the 30-year bonding period plus operation and maintenance costs for the 70 years of project use were then capitalized at 3 percent interest, discounted from 1990 (the time of first need) to 1960 at 3 percent interest, and amortized at 3 percent interest over the 100-year evaluation period for Milford Reservoir.

Water Quality Control

Maintenance of water quality in the Kansas River by flow regulation in addition to provision of adequate waste treatment will increase the potential

of the stream for industrial development, to support aquatic life, and to serve water-oriented recreation activities over 170 miles of river. Improved water quality will enhance the aesthetics of the river for recreational users and for riparian property owners and contribute to a healthful environment for a present population of approximately 700,000 residing in Subarea 6 and an anticipated population of almost 2,700,000 by the end of the design period. With increasing populations and anticipated increases in leisure time, maintenance of water quality to protect aquatic life to enhance recreational use of the Kansas River will be of increasing benefit to the people of the Kansas River Basin. The quality of water distributed through municipal water systems in Topeka, Lawrence, and suburban Kansas City to a present population of 280,000 persons* and to an anticipated population of 2,250,000 will be improved by the more uniform quality and the reduction in the concentration of mineral constituents and residual organic materials. While it is expected that a part of the water used will be drawn from wells in the valley alluvium, water quality will depend largely on the quality of the Kansas River. The physiological effects of high mineral concentrations, especially on transients, and potential tastes and odors requiring additional treatment facilities and increasing operating costs, will be reduced resulting in benefits to domestic water supply users. Some industrial uses require even lower mineral concentrations than are contemplated in this report.[14] Lower objectives established in other areas of the country indicate that present and anticipated industries will benefit from reduced corrosion, scale production, and organism growth resulting from the reduction and greater uniformity of mineral, organic, and nutrient concentrations. For these reasons the benefits resulting from storage in Milford Reservoir for flow regulation for water quality control in the Kansas River are considered to be widespread in scope.

At this time, it is not considered technically or economically feasible to remove natural and industrial minerals or organic materials remaining in waste discharges after adequate waste treatment or other means of control at the source have been provided. Diversion of treatment plant effluent to the Missouri River where greater flows are available may be possible in the Kansas City area and would reduce the total draft on storage requirements, though not below the capacity planned for Milford Reservoir. However, this is not a reasonable alternative for other communities along the Kansas River. Streamflow regulation is therefore the only means presently available to maintain acceptable water quality in the Kansas River for present or projected use. With present economic development, mineral quality objectives are not always met. With completion of presently authorized irrigation projects on the Smoky Hill, Saline, and Solomon Rivers, it is estimated that flow regulation amounting to a draft on storage of about 70,000 acre-feet will be needed in a critical year. By the year 2060, it is estimated that storage facilities to assure a draft on storage of

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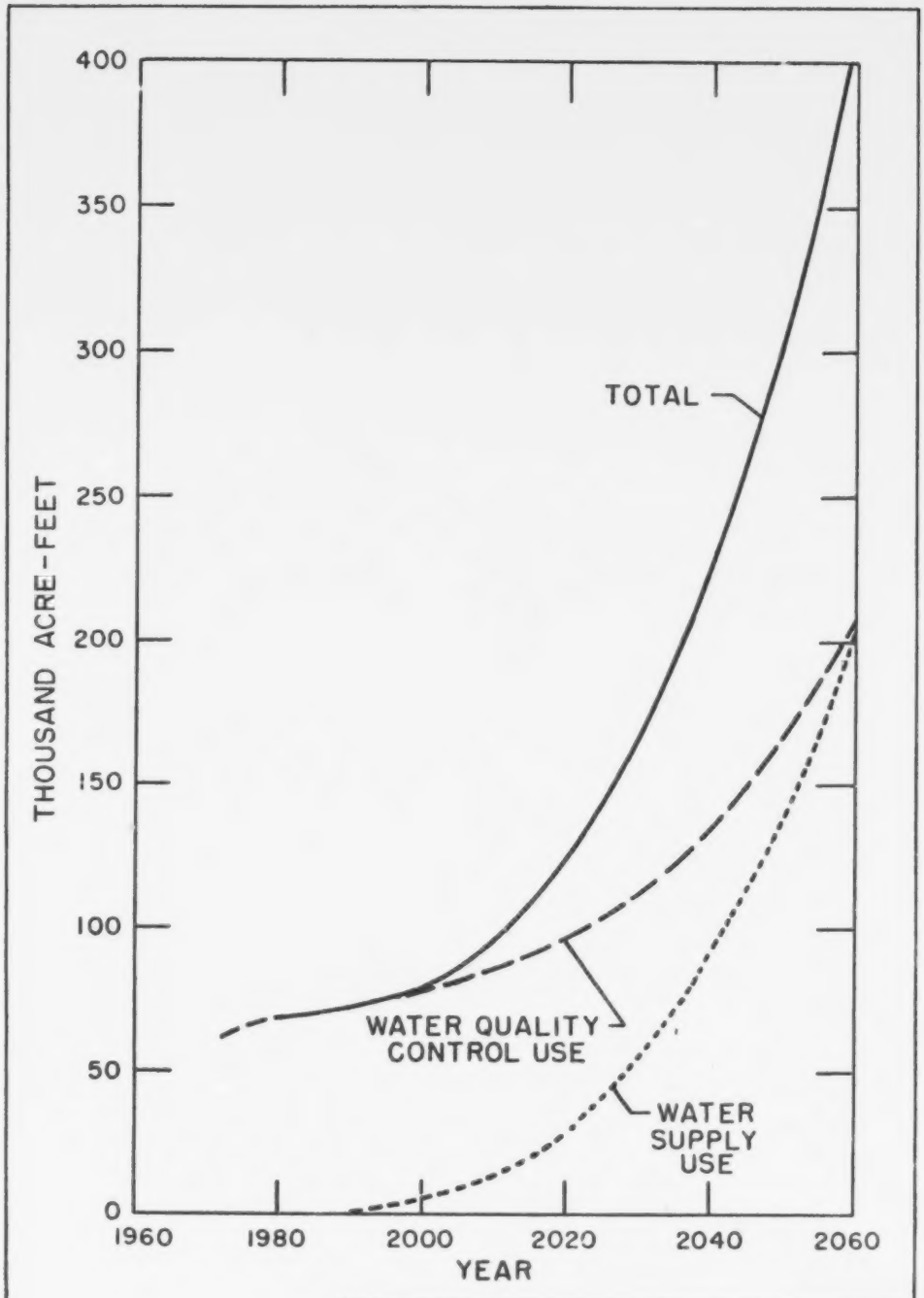
*Assuming quality of water in wells of Johnson County Water District No. 1 is largely dependent on river water quality.

200,000 acre-feet will be needed in a critical year in addition to Perry Reservoir. Since the Corps of Engineers has estimated that the 300,000 acre-feet of storage in Milford Reservoir will be able to sustain a draft on storage of 81,000 acre-feet per year in 90 percent of the years in addition to an estimated normal flow of 90,000 acre-feet, water quality control storage needs will exceed the capacity of Milford Reservoir. The value of storage in Milford Reservoir, together with storage in other projects, to maintain water quality at or above generally accepted water quality objectives to protect major withdrawal uses at Topeka, Lawrence, and suburban Kansas City, and instream uses from Junction City to the Missouri River is considered equal to the cost of the most economical single-purpose reservoir or reservoirs which can supply equivalent streamflow regulation to meet quality control needs. The allocation of 300,000 acre-feet of conservation storage in Milford Reservoir to water quality control purposes will result in benefits estimated to have a value of $620,000 per year, including $50,000 per year required for operation and maintenance. In the Kansas River area and for the storage required a single-purpose reservoir on the Republican River in the vicinity of the Milford Dam site is considered the most economical alternative to storage in the Milford Project. The initial cost is estimated to be $18,000,000 on the basis of average costs of reservoirs of this size constructed by the Corps of Engineers in the project area as presented in the Senate Select Committee report.[37] The estimate of the cost of the alternative single-purpose project should be refined by the construction agency in final project evaluation. Project costs were amortized at 3 percent interest over the 100-year evaluation period for Milford Reservoir.

Additional streamflow regulation facilities or other means of quality control must be developed as economic growth in the Kansas River Valley continues.

Storage in Milford Reservoir can be used for both streamflow regulation and municipal and industrial water supply. Allocation of storage to both purposes would result in benefits having a value between the values specified for either purpose, depending on the proportion allocated to each. Combined flow regulation needs for water supply and quality control are estimated to require a draft of about 410,000 acre-feet in a critical year by 2060, as shown in Figure 13. The combined needs thus far exceed the capabilities of Milford Reservoir. The magnitude of the projected needs indicates that conservation storage for municipal and industrial water supply and for quality control purposes should be considered at all reservoir sites in the Kansas River Basin and that development of conservation storage in Milford Reservoir on the Republican River is an essential part of water resource development of the Kansas River Basin.



WATER RESOURCES STUDY
KANSAS RIVER BASIN - KANSAS
MILFORD RESERVOIR REPORT

ESTIMATED ANNUAL DRAFT ON STORAGE FOR WATER SUPPLY AND QUALITY CONTROL USE

DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VI KANSAS CITY, MO.

FIGURE 13

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Appendix A

Projects in the Approved Plan for Flood Control and Other Purposes

Milford Reservoir Study, Kansas River Basin[24]

Reservoir	Stream	Agency and Status[a]	Drainage Area[b] sq mi	Capacity thousand acre-feet: Flood Control	Conservation	Sediment	Total
Republican Basin							
Bonny	S.Fk.Republican	B/R-E	1,875	129	31	10	170
Pioneer	Arikaree	C/E-A	1,911	87	10	18	115
Trenton (Swanson Lake)	Republican	B/R-E	3,980	134	69	51	254
Enders	Frenchman	B/R-E	2,240	30	34	10	74
Red Willow	Red Willow[d]	B/R-E	632	50	28	10	88
Medicine Cr. (Harry Strunk Lake)	Medicine	B/R-E	838	52	24	15	91
Norton	Prairie Dog[d]	B/R-UC	716	100	31	6	137
Harlan County	Republican	C/E-E	8,561	500	150	200	850
Lovewell	White Rock[d]	B/R-E	354	50	34	8	92
Milford	Republican[d]	C/E-UC	3,796	700	300	160	1,160
Subtotal			24,903	1,832	711	488	3,031
Smoky Hill Basin							
Cedar Bluff	Smoky Hill[d]	B/R-E	5,300	192	172	13	377
Kanopolis	Smoky Hill	C/E-E	2,560	397[c]		53	450
Webster	S.Fk.Solomon	B/R-E	1,198	194	61	6	261
Kirwin	N.Fk.Solomon	B/R-E	1,363	219	76	19	314
Glen Elder	Solomon[d]	B-R-UC	2,869	737	215	24	976
Wilson	Saline[d]	C/E-UC	1,917	510	225	40	775
Woodbine	Lyon Cr.	C/E-A[e]	213	153	66	7	226
Subtotal			15,420	2,402	815	162	3,379
Kansas Basin							
Tuttle	Big Blue	C/E-UC	9,556	1,933	185	228	2,346
Onaga	Vermillion Cr.	C/E-A	287	202	86	14	302
Grove	Soldier Cr.	C/E-A	142	104	45	8	157
Perry	Delaware[d]	C/E-UC	1,117	480	150	140	770
Clinton	Wakarusa	C/E-A	362	255	109	20	384
Subtotal			11,464	2,974	575	410	3,959
Kansas River Basin Total			51,787	7,208	2,101	1,060	10,369

[a] Agency: B/R = Bureau of Reclamation C/E = Corps of Engineers.
Status: A = Authorized E = Existing UC = Under Construction.

[b] Net uncontrolled area above dam site.

[c] 162,500 acre-ft. to be transferred from flood control to irrigation when needed.

[d] Allocations revised since publication of Corps of Engineers Review Report on the Kansas River.

[e] Subject to submission of a further report to Congress.

Appendix B

Description of Major Reservoirs Affecting Streamflow in the Kansas River
Milford Reservoir Study, Kansas River Basin

Reservoir	Kanopolis	Wilson	Glen Elder	Milford	Tuttle Creek	Perry
Stream	Smoky Hill	Saline	Solomon	Republican	Big Blue	Delaware
Status (6/12/62)	Existing	Under Const.	Authorized	Under Const.	Existing	Authorized
Agency[a]	C/E	C/E	B/R	C/E	C/E	C/E
Average Natural Flow, cfs	254[b]	161[c]	428[d]	569[e]	1,686[f]	385[g]
Present Allocation of Storage[h]						
Total Controlled Capacity, acre-ft.	450,000	775,000	976,000[i]	1,160,000	2,346,000	770,000
Usable Conservation, acre-ft.	162,500	225,000	213,300[j]	300,000	185,000	150,000
Mean Annual Reservoir Evaporation[h] acre-ft. per year	18,000[k]	25,000	24,600[l]	20,500	20,000	17,000
Conservation Yield[h]						
Sustained Yield, cfs	78[m]	75[n]	85[o]	150	520[p]	105
Annual Volume, acre-ft per year	56,500	54,300	61,500	108,600	376,500	76,000

[a] Agency: C/E = Corps of Engineers, B/R = Bureau of Reclamation.

[b] USGS flows at Ellsworth, Kansas - affected by Cedar Bluff Reservoir since 1950.

[c] USGS flows at Wilson (near), Kansas.

[d] USGS flows at Beloit, Kansas - affected by Kirwin Reservoir since March 1955 and Webster Reservoir since May 1956.

[e] USCE Hydrology DM - net average flow between Harlan County Dam and Clay Center, Kansas.

[f] USGS flows at Randolph, Kansas.

[g] USGS flows at Valley Falls, Kansas.

[h] C/E Planning Reports and correspondence, unless otherwise noted.

[i] B/R - Planning Reports 26,42

[j] Kansas Water Resources Board - Report to the 1961 Kansas Legislature, 25 November 1960, Table 3.

Appendix C

Industrial Employment for Subareas 1 Through 5
1940, 1950, and 1960
Milford Reservoir Study, Kansas River Basin

Basic Employment Category	1940		1950		1960		1940		1950		1960	
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
	Subarea 1 (Lower Republican River Basin)						Subarea 2 (Upper Republican River Basin)					
Agriculture	12,356	47.2	10,989	45.2	7,110	34.5	23,598	48.3	22,514	45.7	15,500	38.0
Mining	23	0.1	95	0.4	51	0.2	23	0.0	74	0.2	212	0.5
Manufacturing	733	2.8	685	2.8	844	4.1	715	1.5	910	1.8	1,140	2.8
Food & Kindred Products	455	1.7	259	1.1	376	1.8	335	0.7	367	0.7	447	1.1
Printing & Publishing	145	0.6	170	0.7	184	0.9	241	0.5	349	0.7	313	0.8
Fabricated Metals[a]	40	0.2	97	0.4	113	0.5	65	0.1	145	0.3	228	0.6
Others	93	0.4	159	0.7	171	0.8	74	0.2	49	0.1	152	0.4
Basic Industries[b]	13,112	50.1	11,769	48.4	8,005	38.8	24,329	49.8	23,498	47.7	16,942	41.3
Service Industries	9,583	37.9	12,143	49.9	11,967	58.0	18,273	37.4	24,705	50.1	23,290	56.8
Military			100	0.4	54	0.3			22	-	13	-
Unemployment[c]	3,135	12.0	420	1.7	652	3.2	6,248	12.8	1,071	2.2	779	1.9
Total Labor Force	26,170	100.0	24,352	100.0	20,624	100.0	48,850	100.0	49,274	100.0	41,011	100.0
Population	71,433		63,468		53,740		133,691		125,810		108,772	
Labor Force, Percent of Population		36.6		38.4		38.4		36.4		39.2		37.8
	Subarea 3 (Lower Smoky Hill River Basin)						Subarea 4 (Upper Smoky Hill River Basin)					
Agriculture	12,711	32.7	11,219	28.3	6,999	14.2	17,749	42.9	17,548	40.3	12,375	29.2
Mining	599	1.5	488	1.2	447	0.9	1,553	3.8	2,404	5.5	2,137	5.0
Manufacturing	2,295	5.9	2,874	7.2	3,987	8.0	712	1.7	888	2.0	1,312	3.1
Food & Kindred Products	1,170	3.0	1,227	3.1	1,417	2.9	257	0.6	304	0.7	444	1.0
Printing & Publishing	366	0.9	366	0.9	567	1.2	193	0.5	207	0.5	215	0.5
Fabricated Metals[a]	287	0.7	523	1.3	1,048	2.1	101	0.2	142	0.3	123	0.3
Others	464	1.2	758	1.9	995	1.8	161	0.4	235	0.5	430	1.0
Basic Industries[b]	15,605	40.1	14,581	36.8	11,373	23.1	20,024	48.5	20,830	47.8	15,824	37.4
Service Industries	19,240	49.5	24,094	60.8	36,626	74.3	15,779	38.2	21,937	50.3	25,444	60.2
Military			247	0.6	5,831	11.8			33	0.0	33	0.1
Unemployment[c]	4,079	10.5	945	2.4	1,309	2.7	5,554	13.4	800	1.8	1,093	2.6
Total Labor Force	38,924	100.0	39,620	100.0	49,308	100.0	41,347	100.0	43,577	100.0	42,361	100.0
Population	105,517		102,497		121,773		117,467		114,315		109,705	
Labor Force, Percent of Population		36.9		38.6		40.5		35.1		38.1		38.7

Appendix C (Cont.)

Basic Employment Category	1940		1950		1960		1940		1950		1960	
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
	Subarea 5 (Big Blue River Basin)						Subareas 1 through 5					
Agriculture	30,796	43.4	34,451	40.7	23,974	31.6	103,203	43.0	96,721	40.4	66,048	28.8
Mining	126	0.1	203	0.2	134	0.2	2,324	1.0	3,264	1.4	2,981	1.3
Manufacturing	3,562	4.2	5,056	6.0	5,851	7.7	8,017	3.3	10,413	4.4	13,074	5.7
Food & Kindred Products	1,138	1.5	1,463	1.7	1,531	2.0	3,363	1.4	3,620	1.5	4,317	1.9
Printing & Publishing	660	0.9	642	0.6	680	0.9	1,605	0.7	1,734	0.7	2,107	0.9
Fabricated Metals[a]	723	0.9	1,455	1.7	1,612	2.1	1,216	0.5	2,362	1.0	3,140	1.4
Others	1,041	1.3	1,496	1.8	1,801	2.4	1,833	0.8	2,697	1.1	3,510	1.5
Basic Industries[b]	40,484	47.7	39,710	46.9	29,959	39.6	113,544	47.3	110,398	46.1	82,103	35.8
Service Industries	34,109	40.2	41,505	49.1	43,734	57.7	97,324	40.5	124,304	51.9	141,061	61.6
Military			176	0.2	95	0.1			575	0.2	6,026	2.6
Unemployment[c]	10,218	12.0	1,422	1.7	1,949	2.6	29,233	12.2	4,658	1.9	5,882	2.6
Total Labor Force	84,810	100.0	84,657	100.0	75,742	100.0	240,101	100.0	239,440	100.0	229,046	100.0
Population	227,914		216,125		201,859		656,022		622,195		590,849	
Labor Force, Percent of Population		37.2		39.2		37.6		36.6		38.6		38.4

[a] Includes machinery, electrical equipment, motor vehicles and transportation equipment.

[b] Defined in this study as all employment in manufacturing and extractive industries; all other is included in service industries.

[c] In 1940, includes those employed part time or temporarily by WPA, NYA, etc.

Appendix I

Industrial Employment for Subareas 6
1940, 1950, and 1960
Milford Reservoir Study, Kansas River Basin

Basic Employment Category	1940		1950		1960		1940		1950		1960	
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
	Kansas City (Johnson and Wyandotte Counties)						Lawrence (Douglas County)					
Agriculture	3,981	5.5	2,985	3.2	1,799	1.4	2,247	23.1	1,851	15.6	1,178	6.8
Mining	235	0.3	252	0.3	256	0.2	20	0.2	26	0.2	37	0.2
Manufacturing	15,667	21.6	23,351	25.6	30,965	24.2	619	6.4	1,060	8.9	2,370	13.7
Furniture, Lumber, & Wood Products	586	0.8	792	0.9	960	0.7	7	0.1	31	0.3	24	0.1
Primary Metals	2,196	3.0	731	0.9	643	0.5	39	0.4	2	0.0	12	0.1
Fabricated Metal a/			4,883	5.4	8,668	6.8			118	1.0	107	0.6
Other Durables	224	0.3	1,407	1.5	2,737	2.1	1	0.0	81	0.7	153	0.9
Food & Kindred Products	6,534	9.0	7,461	8.2	6,066	4.7	194	2.0	304	2.6	294	1.7
Textiles	42	0.1	232	0.3	92	0.1	1	0.0	2	0.0	263	1.5
Apparel	1,412	1.9	1,573	1.7	1,646	1.3	2	0.0	6	0.1	12	0.1
Printing & Publishing	1,504	2.1	1,557	1.7	3,289	2.6	171	1.8	215	1.8	447	2.6
Chemicals & Allied Products	1,392	1.9	1,767	1.9	3,143	2.5	2	0.0	20	0.2	704	4.1
Other Nondurables	1,777	2.5	2,888	3.2	3,714	2.9	202	2.1	281	2.4	354	2.1
Basic Industries b/	19,883	27.5	26,588	29.1	33,000	25.8	2,886	29.6	2,937	24.7	3,585	20.8
Service Industries	40,077	55.3	61,589	67.6	89,682	70.2	5,850	60.1	8,727	73.4	13,187	76.4
Military			800		1,707				65		106	
Unemployment c/	12,472	17.2	2,952	3.2	5,132	4.0	1,001	10.3	221	1.9	488	2.8
Total Labor Force	72,432	100.0	91,052	100.0	127,814	100.0	9,737	100.0	11,885	100.0	17,260	100.0
Population	178,398		228,101		329,287		25,171		34,006		43,702	
Labor Force, Percent of Population		40.6		39.9		38.8		38.7		34.9		39.5
	Topeka (Shawnee County)						Manhattan (Riley County)					
Agriculture	2,549	6.9	2,367	5.2	1,260	2.2	1,902	22.8	1,484	10.2	1,436	7.5
Mining	111	0.3	68	0.2	54	0.1	15	0.2	23	0.2	32	0.2
Manufacturing	4,065	11.0	6,023	13.3	5,836	10.0	292	3.5	314	2.2	435	2.3
Furniture, Lumber, & Wood Products	157	0.4	184	0.4	77	0.1	8	0.1	7	0.0	6	0.0
Primary Metals	369	1.0	96	0.2	64	0.1	20	0.2	3	0.0	0	0.0
Fabricated Metals c/			421	0.9	459	0.8			53	0.4	72	0.4
Other Durables	28	0.1	164	0.4	168	0.3	30	0.2	19	0.1	35	0.2
Food & Kindred Products	1,905	5.2	2,350	5.2	1,300	2.1	142	1.7	118	0.8	146	0.8
Textiles	6	0.0	22	0.0	7	0.0	0	0.0	1	0.0	4	0.0
Apparel	57	0.2	53	0.1	52	0.1	5	0.1	5	0.0	4	0.0
Printing & Publishing	1,461	4.0	1,697	3.8	1,736	3.0	77	0.9	80	0.6	141	0.7
Chemicals & Allied Products	29	0.1	74	0.2	416	0.7	0	0.0	6	0.0	10	0.1
Other Nondurables	46	0.1	962	2.1	1,497	2.6	30	0.2	22	0.2	11	0.1
Basic Industries b/	6,795	18.4	8,458	18.7	7,150	12.3	2,209	26.5	1,821	12.6	1,903	9.9
Service Industries	25,135	68.2	35,559	78.6	49,281	84.7	5,217	62.6	12,544	86.6	16,862	88.0
Military			116		5,700				4,665	32.2	6,500	34.0
Unemployment c/	4,998	13.6	1,212	2.7	1,758	3.0	905	10.9	118	0.8	403	2.1
Total Labor Force	36,858	100.0	45,269	100.0	58,189	100.0	8,331	100.0	14,483	100.0	19,168	100.0
Population	91,247		105,418		141,286		20,617		31,405		41,914	
Labor Force, Percent of Population		40.4		42.9		41.2		40.4		43.3		45.7

Appendix B (Cont.)

Basic Employment Category	1960 No.	1960 Pct.	1990 No.	1990 Pct.	1960 No.	1960 Pct.	1960 No.	1960 Pct.	1990 No.	1990 Pct.	1990 No.	1990 Pct.
	Junction City (Geary County)						Other					
Agriculture	907	14.2	840	8.1	598	4.1	16,866	37.9	15,096	33.6	9,809	20.2
Mining	11	0.2	30	0.2	30	0.2	84	0.2	160	0.4	120	0.3
Manufacturing	445	7.1	197	1.9	227	1.7	2,540	5.7	3,459	7.7	5,350	11.0
Furniture, Lumber, & Wood Products	2	0.0	1	0.0	0	0.0	371	0.8	420	0.9	283	0.6
Primary Metals	16	0.2	0	0.0	0	0.0	680	1.5	175	0.4	506	1.3
Fabricated Metals 2/			25	0.3	16	0.1			1,075	2.4	998	2.1
Other Durables	8	0.1	22	0.2	40	0.3	22	0.0	79	0.2	213	0.5
Food & Kindred Products	70	1.0	90	0.9	102	0.8	872	2.0	919	2.0	1,040	2.4
Textiles	0	0.0	1	0.0	0	0.0	5	0.0	4	0.0	44	0.1
Apparel	0	0.0	0	0.0	17	0.1	163	0.4	149	0.3	584	1.3
Printing & Publishing	46	0.7	42	0.4	48	0.4	372	0.8	396	0.9	810	1.8
Chemicals & Allied Products	0	0.0	1	0.0	0	0.0	20	0.0	65	0.2	169	0.4
Other Nondurables	3	0.0	3	0.0	4	0.0	33	0.1	189	0.3	503	1.3
Basic Industries 3/	1,143	16.4	1,018	10.1	788	6.0	19,490	43.8	18,715	41.7	14,201	32.3
Service Industries	4,777	68.8	8,753	89.5	11,953	91.6	19,960	44.8	25,253	56.3	28,399	64.6
Military			4,736	47.8	7,000	53.7			2,338		2,557	
Unemployment 4/	1,032	14.8	123	1.2	302	2.4	5,094	11.4	907	2.0	1,390	3.1
Total Labor Force	6,952	100.0	9,894	100.0	13,040	100.0	44,544	100.0	44,875	100.0	43,990	100.0
Population	15,220		21,671		29,779		129,429		119,938		182,485	
Labor Force, Percent of Population		45.7		45.7		43.8		34.4		37.4		24.1

	Geary Co. - Total					
Agriculture	16,530	16.0	24,527	11.1	15,100	5.4
Mining	476	0.5	599	0.3	525	0.2
Manufacturing	23,338	13.0	34,196	15.8	45,019	16.1
Furniture, Lumber, & Wood Products	1,131	0.6	1,437	0.7	1,530	0.5
Primary Metals	1,322	1.9	1,007	0.5	1,303	0.5
Fabricated Metals 2/			6,585	3.0	10,256	3.7
Other Durables	331	0.2	1,772	0.8	4,366	1.2
Food & Kindred Products	9,717	5.4	11,243	5.2	9,010	3.2
Textiles	54	0.0	262	0.1	410	0.1
Apparel	1,639	0.9	1,786	0.8	2,115	0.8
Printing & Publishing	3,638	2.0	3,985	1.8	6,471	2.3
Chemicals & Allied Products	1,443	0.8	1,953	0.9	4,449	1.6
Other Nondurables	3,061	1.2	4,305	2.0	6,160	2.2
Basic Industries 3/	52,136	29.5	59,480	27.4	60,644	21.7
Service Industries	101,536	56.5	152,425	70.1	209,984	74.9
Military			12,700	5.8	23,530	8.4
Unemployment 5/	25,307	14.3	5,511	2.5	9,449	3.4
Total Labor Force	179,984	100.0	217,416	100.0	279,451	100.0
Population	400,884		542,617		707,471	
Labor Force, Percent of Population		30.9		40.1		39.5

1/Includes machinery, electrical equipment, motor vehicles and transportation equipment.

2/Defined in this study as all employment in manufacturing and extractive industries; all other is included in service industries.

3/In 1960, includes those employed part time or temporarily by AAA, etc.

Appendix E

Estimated Industrial Employment for Subareas 6
1980, 2010, and 2060
Milford Reservoir Study, Kansas River Basin

Basic Employment Category	1980		2010		2060		1980		2010		2060	
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
	Kansas City (Johnson and Wyandotte Counties)						Lawrence (Douglas County)					
Agriculture	1,000	0.6	500	0.2	500	0.1	800	3.1	500	1.1	500	0.7
Mining	250	0.1	250	0.1	100	0.0	50	0.2	50	0.1	50	0.1
Manufacturing	41,800	23.5	61,000	22.1	98,700	22.2	5,150	19.8	9,450	20.1	16,200	21.5
Furniture, Lumber, & Wood Products	1,200	0.7	1,500	0.5	2,500	0.6	50	0.2	150	0.3	400	0.5
Primary Metals	1,000	0.6	1,600	0.6	2,700	0.6	0	0.0	0	0.0	0	0.0
Fabricated Metals[2/]	15,300	8.6	25,000	9.1	42,000	9.4	1,500	5.8	3,000	6.4	5,000	6.6
Other Durables	3,270	1.8	4,000	1.5	6,500	1.5	200	0.8	400	0.9	1,000	1.3
Food & Kindred Products	6,800	3.8	8,500	3.1	10,500	2.4	500	1.9	900	1.9	1,500	2.0
Textiles	300	0.2	800	0.3	1,000	0.4	300	1.2	400	0.9	500	0.7
Apparel	2,500	1.4	4,200	1.5	7,000	1.6	500	1.9	800	1.7	1,500	2.0
Printing & Publishing	3,500	2.0	4,700	1.7	7,900	1.8	700	2.7	1,500	3.2	2,500	3.7
Chemicals & Allied Products	3,540	2.0	5,000	1.8	9,000	2.0	900	3.5	1,500	3.2	2,000	2.6
Other Nondurables	4,500	2.5	5,500	2.0	9,000	2.0	500	1.9	800	1.7	1,500	2.0
Basic Industries[3/]	44,250	24.9	61,750	22.4	99,300	22.3	6,000	23.1	10,000	21.3	16,750	22.0
Service Industries	126,650	71.1	203,250	73.6	327,700	73.6	19,000	73.1	35,100	74.7	56,250	74.0
Military												
Unemployment	7,100	4.0	11,000	4.0	18,000	4.0	1,000	3.8	1,900	4.0	3,000	4.0
Total Labor Force	178,000	100.0	276,000	100.0	445,000	100.0	26,000	100.0	47,000	100.0	76,000	100.0
Population	480,000		770,000		1,350,000		73,000		130,000		230,000	
Labor Force, Percent of Population		37		36		33		37		36		33
	Topeka (Shawnee County)						Manhattan (Riley County)					
Agriculture	800	0.9	500	0.4	500	0.2	1,700	5.9	1,000	3.6	1,000	2.5
Mining	50	0.1	50	0.0	50	0.0	50	0.2	50	0.2	50	0.1
Manufacturing	10,950	12.6	21,350	16.6	35,500	16.3	600	4.4	2,350	8.4	4,700	11.7
Furniture, Lumber, & Wood Products	300	0.3	450	0.3	600	0.3	50	0.2	150	0.5	300	0.7
Primary Metals	50	0.0	100	0.1	300	0.2	0	0.0	0	0.0	0	0.0
Fabricated Metals[2/]	3,500	4.1	9,000	7.0	17,000	7.7	150	0.7	600	2.1	1,800	4.5
Other Durables	300	0.3	1,000	0.8	1,500	0.8	50	0.2	100	0.4	200	0.5
Food & Kindred Products	1,900	2.1	2,500	1.9	4,000	1.8	300	1.5	600	2.1	1,000	2.5
Textiles	0	0.0	100	0.1	100	0.0	0	0.0	0	0.0	0	0.0
Apparel	500	0.6	1,500	1.2	2,000	0.9	50	0.2	350	1.2	500	1.3
Printing & Publishing	2,000	2.3	3,000	2.3	4,500	2.0	300	1.6	450	1.6	700	1.8
Chemicals & Allied Products	500	0.6	600	0.6	1,000	0.5	50	0.2	50	0.2	100	0.2
Other Nondurables	2,000	2.3	2,900	2.2	4,500	2.0	50	0.2	50	0.2	100	0.2
Basic Industries[3/]	11,700	13.6	21,900	17.0	36,250	16.5	2,150	10.5	3,400	12.1	5,750	14.4
Service Industries	70,300	82.3	101,900	79.0	174,250	79.5	17,450	85.5	23,500	83.9	32,650	81.6
Military							7,000	34.3	7,000	25.0	7,000	17.5
Unemployment	3,500	4.0	5,000	4.0	8,500	4.0	800	4.0	1,100	4.0	1,600	4.0
Total Labor Force	86,000	100.0	129,000	100.0	220,000	100.0	20,400	100.0	28,000	100.0	40,000	100.0
Population	230,000		355,000		670,000		53,000		75,000		130,000	
Labor Force, Percent of Population		37.5		36.5		33		38.5		37		33

Appendix E (Cont.)

Basic Employment Category	1960		2010		2060		1960		2010		2060	
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
	Junction City (Geary County)						Other					
Agriculture	400	2.7	300	1.5	300	0.9	5,900	13.7	5,500	11.2	5,500	8.3
Mining	50	0.3	50	0.2	50	0.2	650	1.5	650	1.3	400	0.6
Manufacturing	700	4.7	2,150	10.5	4,500	13.6	7,200	16.7	9,900	20.2	13,700	20.8
Furniture, Lumber, & Wood Products	50	0.3	150	0.7	200	0.6	500	0.6	400	0.8	500	0.8
Primary Metals	0	0.0	0	0.0	0	0.0	650	1.5	800	1.6	1,000	1.5
Fabricated Metals a/	150	1.0	600	2.9	2,000	6.1	1,800	4.2	3,200	6.5	5,000	7.6
Other Durables	50	0.3	200	1.0	300	0.9	300	0.7	400	0.8	700	1.1
Food & Kindred Products	200	1.4	400	2.0	800	2.4	1,400	3.3	1,600	3.3	2,000	3.0
Textiles	0	0.0	0	0.0	0	0.0	100	0.2	200	0.4	200	0.3
Apparel	50	0.3	250	1.2	400	1.2	800	1.9	1,000	2.0	1,500	2.3
Printing & Publishing	100	0.7	250	1.2	400	1.2	800	1.9	800	1.6	800	1.2
Chemicals & Allied Products	50	0.3	150	0.7	200	0.6	400	0.9	700	1.4	1,000	1.5
Other Nondurables	50	0.3	150	0.7	200	0.6	700	1.6	800	1.6	1,000	1.5
Basic Industries b/	1,150	7.8	2,500	12.2	4,850	14.7	13,750	32.0	16,050	32.8	19,600	29.7
Service Industries	13,050	88.2	17,200	83.9	26,850	81.3	27,550	64.0	30,950	63.2	43,800	66.4
Military	7,000	47.3	7,000	34.1	7,000	21.2						
Unemployment	600	4.0	800	4.0	1,300	4.0	1,700	4.0	2,000	4.0	2,600	4.0
Total Labor Force	14,800	100.0	20,500	100.0	33,000	100.0	43,000	100.0	49,000	100.0	66,000	100.0
Population	37,000		55,000		100,000		120,000		140,000		200,000	
Labor Force, Percent of Population		40		37		33		36		35		33
	Subarea 6 - Total											
Agriculture	10,100	2.7	8,300	1.5	8,300	0.9						
Mining	1,100	0.3	1,100	0.2	700	0.1						
Manufacturing	66,600	18.1	106,200	19.3	173,600	19.7						
Furniture, Lumber, & Wood Products	1,800	0.5	2,800	0.5	4,500	0.5						
Primary Metals	1,700	0.5	2,500	0.5	4,000	0.5						
Fabricated Metals a/	22,400	6.1	41,400	7.5	72,800	8.3						
Other Durables	4,100	1.1	6,300	1.1	10,500	1.2						
Food & Kindred Products	11,000	3.0	14,500	2.6	19,800	2.2						
Textiles	700	0.2	1,500	0.3	2,400	0.3						
Apparel	4,400	1.2	8,100	1.5	12,900	1.5						
Printing & Publishing	7,300	2.0	10,700	1.9	17,100	1.9						
Chemicals & Allied Products	5,400	1.5	8,200	1.5	13,300	1.5						
Other Nondurables	7,800	2.1	10,200	1.9	16,300	1.9						
Basic Industries b/	77,800	21.1	115,600	21.0	182,600	20.8						
Service Industries	275,700	74.9	411,900	75.0	662,000	75.2						
Military	24,000	6.5	24,000	4.4	24,000	2.7						
Unemployment	14,700	4.0	22,000	4.0	35,400	4.0						
Total Labor Force	368,200	100.0	549,500	100.0	880,000	100.0						
Population	990,000		1,525,000		2,670,000							
Labor Force, Percent of Population		37		36		33						

a/ Includes machinery, electrical equipment, motor vehicles and transportation equipment.

b/ Defined in this study as all employment in manufacturing and extractive industries; all other is included in service industries.

Appendix F

Municipal Water Use in Subarea 6
Milford Reservoir Study, Kansas River Basin

Community	Population 1960	Estimated Population Served 1963	Municipal Use, mgd		Rated Plant Capacity mgd
			Average	Maximum	
Shallow Well Supplies					
Alma	838	800	0.05	0.10	0.42
Belvue	197	179	0.01	0.02	0.03
Bonner Springs[a]	3,171	3,350	0.25	0.60	1.00
Circleville	151	150	0.01	0.03	0.05
Delia	163	160	0.01	0.02	0.04
Denison	184	175	0.015	0.3	0.04
De Soto[a]	1,271	1,475	0.140	0.3	0.52
Easton	320	350	0.04	0.07	0.072
Emmett	128	150	0.01	0.02	0.03
Eudora[a]	1,526	1,565	0.13	0.25	0.36
Everest	348	350	0.04	0.06	0.14
Goff	259	250	0.01	0.02	0.15
Havensville	166	180	0.02	0.05	0.11
Hoyt	283	300	0.01	0.02	0.02
Johnson Co. Water District No. 1[a][b]	-	110,000	8.0	15.0	20.0[c]
Junction City[d]	18,700	20,750	2.50	5.5	6.0
LeCompton	304	325	0.03	0.06	0.072

Appendix F (Cont.)

Community	Population 1960	Estimated Population Served 1963	Municipal Use, mgd Average	Maximum	Rated Plant Capacity mgd
		Shallow Well Supplies (Cont.)			
Linwood	304	325	0.03	0.06	0.072
Mayetta	218	200	0.01	0.03	0.05
McLouth	494	475	0.02	0.04	0.09
Manhattan[a/]	22,993	21,500	3.02	5.14	7.50
Maple Hill	244	275	0.02	0.04	0.04
Muscotah	228	225	0.02	0.04	0.04
North Hills Water Co.		755	0.06	0.10	0.18
Ogden	1,780	2,100	0.12	0.20	0.40
Rossville	797	800	0.08	0.10	0.14
RWD[e/] No. 1, Douglas Co.	-	500	0.03	0.05	0.07
RWD No. 1, Johnson Co.	-	325	0.03	0.05	0.10
RWD No. 1, Jefferson Co.	-	750	0.06	0.10	0.20
RWD No. 1, Shawnee Co.	-	305	0.03	0.05	0.08
RWD No. 2, Shawnee Co.	-	560	0.05	0.09	0.18
RWD No. 3, Shawnee Co.	-	450	0.05	0.08	0.21
St. Marys	1,509	1,400	0.12	0.30	0.72
Silver Lake	392	350	0.03	0.08	0.10
Soldier	171	175	0.01	0.02	0.02
Tonganoxie	1,354	1,500	0.09	0.20	0.40
Wamego[a/]	2,363	2,500	0.30	0.60	1.00

Appendix F (Cont.)

Community	Population 1960	Estimated Population Served 1963	Municipal Use, mgd Average	Municipal Use, mgd Maximum	Rated Plant Capacity mgd
Shallow Well Supplies (Cont.)					
Westmoreland	460	400	0.02	0.08	0.08
Wetmore	390	375	0.04	0.08	0.28
Winchester	458	300	0.01	0.02	0.07
Total	62,235	176,654	15.426	29.950	40.856
Deep Well Supplies					
Alta Vista	400	400	0.02	0.05	0.07
Effingham	564	500	0.086	0.16	-
Nortonville	595	625	0.05	0.10	0.072
Perry	495	480	0.05	0.07	0.14
White City	459	550	0.04	0.10	0.14
Total	2,513	2,555	0.246	0.38	0.422
Stream Water Supplies					
Lawrence f/	32,858	35,000	4.7	10.0	11.0
Onaga	850	830	0.07	0.11	0.14
RWD No. 8, Shawnee Co.	-	625	0.04	0.08	0.115
Topeka f/	119,484	135,000	13.4	23.0	40.0
Valley Falls	1,193	1,175	0.13	0.15	0.37
Total	154,385	172,630	18.29	33.40	51.675

Appendix F (Cont.)

Community	Population 1960	Estimated Population Served 1963	Municipal Use, mgd Average	Municipal Use, mgd Maximum	Rated Plant Capacity mgd
		Impounded Water Supplies			
Carbondale	664	250	0.03	0.05	-
Holton	3,028	2,600	0.19	0.45	0.52
Horton	2,361	2,800	0.25	0.55	1.27
Olathe [b]	10,987	10,750	1.35	2.5	2.50
Oskaloosa	807	775	0.07	0.14	0.28
Sabetha	2,318	2,400	0.30	0.60	0.62
Total	20,165	19,575	2.19	4.29	5.19
Municipal Total	239,298	371,414	36.152	74.52	98.143

[a] Wells in alluvium of the Kansas River.
[b] Surface water supply under consideration.
[c] Includes purchase of 6.5 mgd from Kansas City, Kansas.
[d] Wells in alluvium of the Republican River.
[e] RWD= Rural Water District.
[f] Kansas River.

Appendix G

Estimated Future Water Use in Subarea 6 in Average Year[a/]
Milford Reservoir Study, Kansas River Basin

Community or Area	Population	Unit Use gpcd	Municipal Use, mgd Average	Municipal Use, mgd Maximum	Industrial Use mgd
		1960			
Junction City	19,000	143	2.72	4.08	0.5
Manhattan	23,000	140	3.22	4.82	0.5
Smaller Towns & Rural Areas above Topeka	61,200	140	8.55	12.82	2.0
Topeka	141,200	105	14.85	22.25	7.0
Smaller Towns & Rural Areas below Topeka	61,200	140	8.55	12.82	2.0
Lawrence	32,858	150	6.56	9.83	6.3
Kansas City Suburban[b/]	163,000	120	19.55	29.30	8.8
Total	512,420		64.0	95.92	27.10
Total, Municipal and Industrial			91.1	123.0	-
		1980			
Junction City	30,000	150	4.5	6.75	1.1
Manhattan	34,000	150	5.1	7.6	1.3
Smaller Towns & Rural Areas above Topeka	60,000	150	9.0	13.5	4.5
Topeka	230,000	150	34.5	51.7	11.4
Smaller Towns & Rural Areas below Topeka	60,000	150	9.0	13.5	4.5
Lawrence	70,000	160	11.2	16.8	11.4
Kansas City Suburban[b/]	230,000	135	31.0	49.7	17.3
Total	714,000		104.3	159.6	51.5
Total, Municipal and Industrial			155.8	211.0	-

Appendix G (Cont.)

Community or Area	Population	Unit Use gpcd	Municipal Use, mgd Average	Municipal Use, mgd Maximum	Industrial Use mgd
		2010			
Junction City	50,000	160	8.0	12.0	2.6
Manhattan	60,000	160	9.6	14.4	3.3
Smaller Towns & Rural Areas above Topeka	70,000	160	11.2	16.8	10.0
Topeka	355,000	160	56.8	85.2	24.8
Smaller Towns & Rural Areas below Topeka	70,000	160	11.2	16.8	10.0
Lawrence	130,000	170	22.1	33.1	24.9
Kansas City Suburban[b]	420,000	150	63.0	94.5	42.3
Total	1,155,000		181.9	272.8	117.9
Total, Municipal and Industrial			299.8	390.7	-
		2060			
Junction City	100,000	175	17.5	26.2	6.4
Manhattan	120,000	175	21.0	31.5	8.3
Smaller Towns & Rural Areas above Topeka	100,000	175	17.5	26.2	22.7
Topeka	670,000	175	117.0	175.8	62.8
Smaller Towns & Rural Areas below Topeka	100,000	175	17.5	26.2	22.7
Lawrence	230,000	175	40.3	60.4	69.0
Kansas City Suburban[b]	850,000	160	136.0	204.0	151.6
Total	2,170,000		367	550	343
Total, Municipal and Industrial			710	893	-

[a]Water use in a drouth year would be higher.

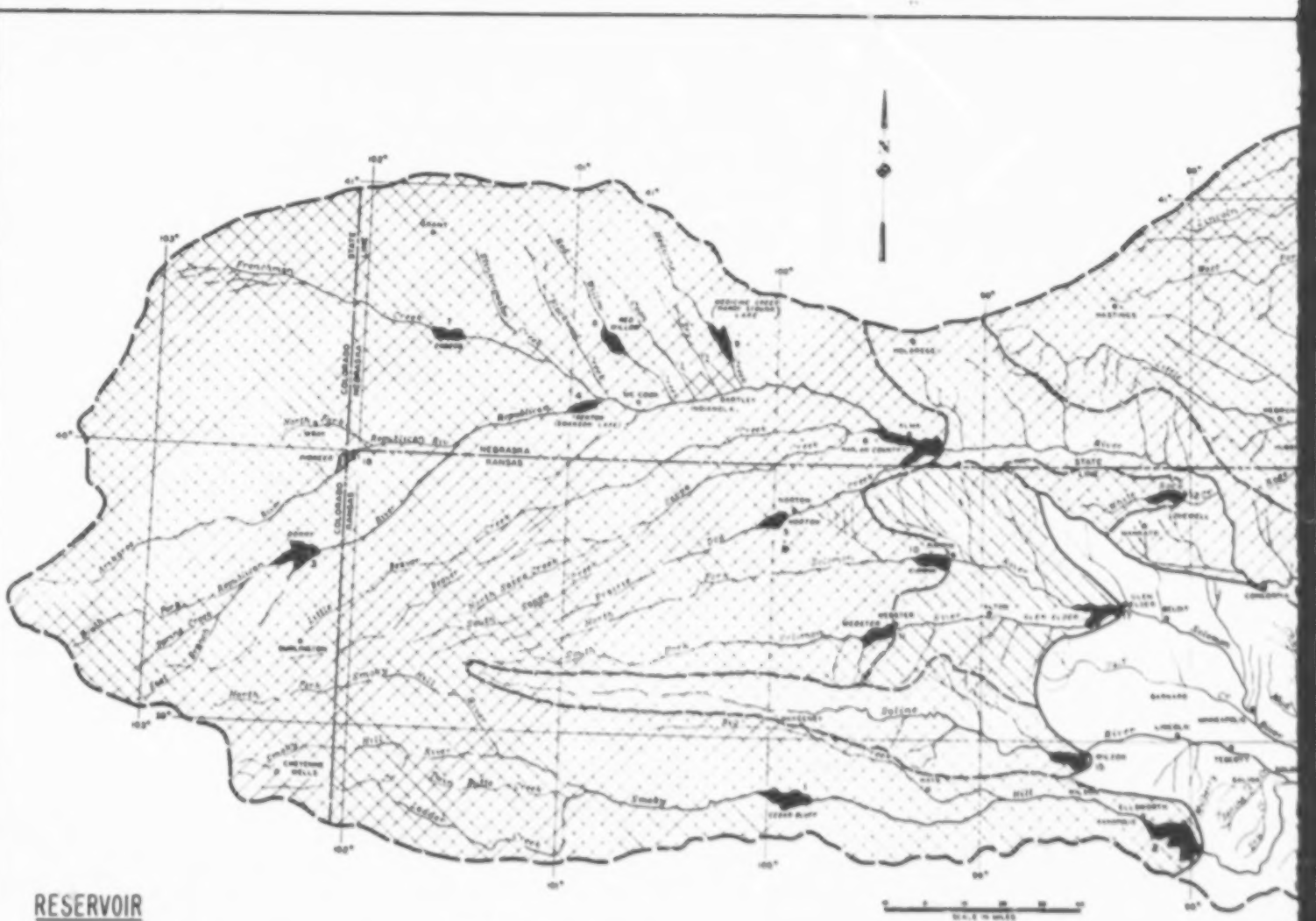
[b]Estimates suburban area that will secure its water supply from the Kansas River.

Appendix H

Estimated Future Organic Waste Loads Tributary to the Kansas River after Adequate Treatment Milford Reservoir Study, Kansas River Basin

Location	Organic Waste Load, Population Equivalents			
	1960 a/	1980	2010	2060
Junction City				
Municipal	3,800	4,800	5,600	12,200
Industrial	800	1,350	2,100	5,100
Total	4,600	6,150	7,700	17,300
Manhattan				
Municipal	4,400	5,400	6,700	14,700
Industrial	800	1,650	2,600	6,600
Total	5,200	7,050	9,300	21,300
Small Communities & Rural Areas Above Topeka				
Municipal	12,000	9,350	7,900	12,200
Industrial	3,200	5,400	8,000	18,200
Total	15,200	14,750	15,900	30,400
Topeka				
Municipal	20,800	36,200	39,800	82,000
Industrial	11,200	13,600	19,800	50,200
Total	32,000	49,800	59,600	132,200
Small Communities & Rural Areas Below Topeka				
Municipal	12,000	9,350	7,900	12,200
Industrial	3,200	5,400	8,000	18,200
Total	15,200	14,750	15,900	30,400
Lawrence				
Municipal	10,400	11,700	15,500	28,200
Industrial	11,200	13,600	19,900	55,200
Total	21,600	25,300	35,400	83,400
Suburban Kansas City				
Municipal	7,000	32,550	44,100	95,200
Industrial	14,000	20,700	33,800	121,300
Total	21,000	53,250	77,900	216,500
Total	114,800	171,030	221,700	531,500

a/ Assumes entire waste load is collected, treated, and discharged to the Kansas River or tributaries.



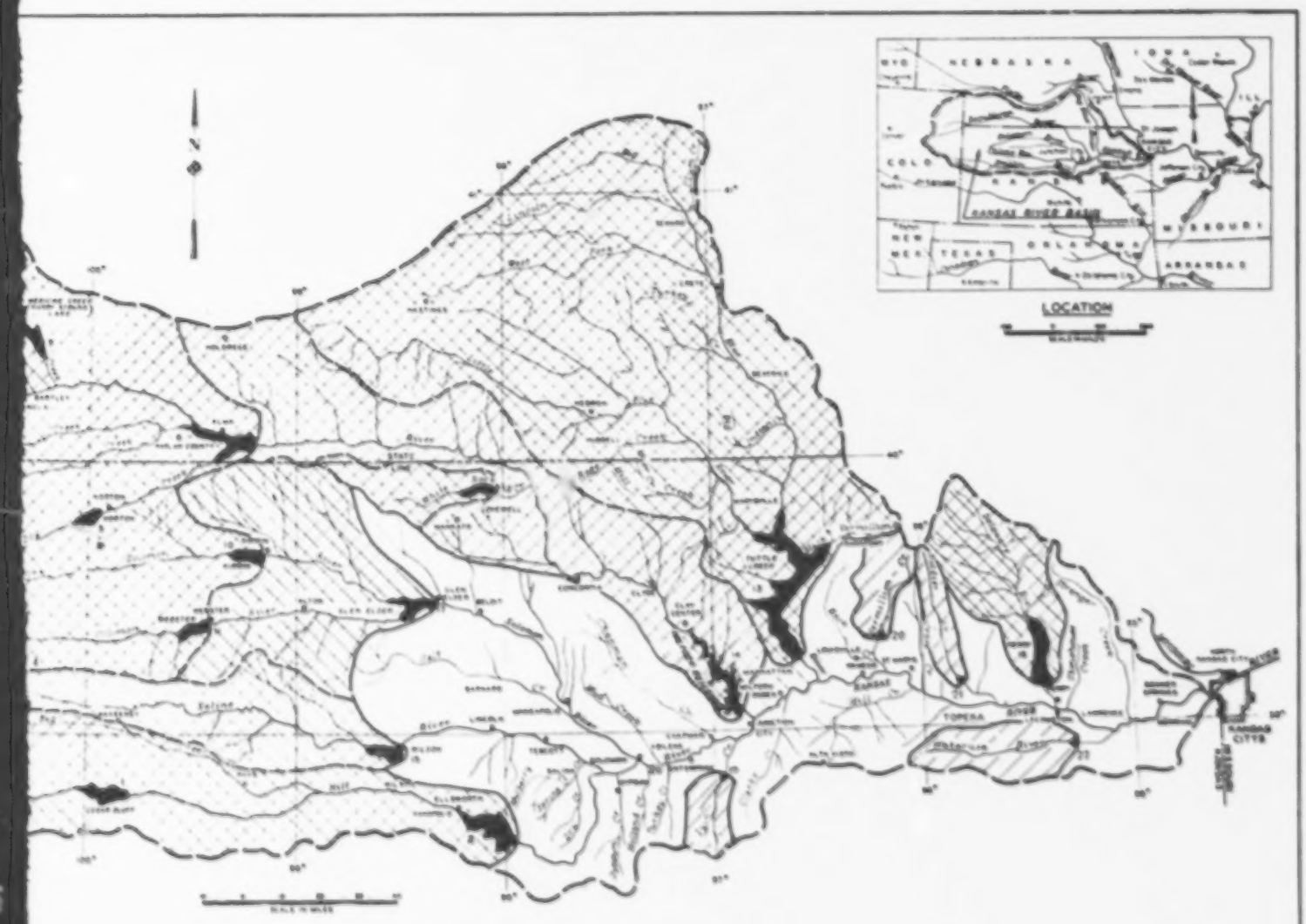
RESERVOIR NUMBER	NAME	STREAM
COMPLETED OR UNDER CONSTRUCTION		
1	CEDAR BLUFF	SMOKY HILL RIVER
2	KANOPOLIS	SMOKY HILL RIVER
3	BONNY	SOUTH FORK REPUBLICAN RIVER
4	TRENTON (Swanson Lake)	REPUBLICAN RIVER
5	NORTON	PRAIRIE DOG CREEK
6	HARLAN COUNTY	REPUBLICAN RIVER
7	ENDERS	FRENCHMANS CREEK
8	RED WILLOW	RED WILLOW CREEK
9	MEDICINE CR. (Harry Strunk Lake)	MEDICINE CREEK
10	KIRWIN	NORTH FORK SOLOMON RIVER
11	WEBSTER	SOUTH FORK SOLOMON RIVER
12	LOVEWELL	WHITE ROCK CREEK
13	TUTTLE CR.	BIG BLUE RIVER
14	MILFORD	REPUBLICAN RIVER
15	WILSON	SALINE RIVER
16	PERRY	DELAWARE
17	GLEN ELDER	SOLOMON RIVER
18	PIONEER	ARIKAREE RIVER
AUTHORIZED BUT NOT STARTED		
19	WOODBINE	LYON CREEK
20	ONAGA	VERMILLION CREEK
21	GROVE	SOLDIER CREEK
22	CLINTON	WAKARUSA RIVER

LEGEND

RESERVOIRS

COMPLETED OR UNDER CONSTRUCTION

AUTHORIZED BUT NOT STARTED



RIVER

LEGEND

RESERVOIRS

COMPLETED OR UNDER CONSTRUCTION

AUTHORIZED BUT NOT STARTED

WATER RESOURCES STUDY
KANSAS RIVER BASIN - KANSAS
MILFORD RESERVOIR REPORT

LOCATION MAP

DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VI KANSAS CITY, MO.

FIGURE 1